ILLUSTRATIONS

OF THE

THEORY AND PRACTICE OF VENTILATION.

[See page 76.

ILLUSTRATIONS

OF THE

THEORY AND PRACTICE OF VENTILATION,

WITH REMARKS ON

WARMING, EXCLUSIVE LIGHTING, AND THE COMMUNICATION OF SOUND.

BY DAVID BOSWELL REID, M.D., F.R.S.E.,

FELLOW OF THE ROYAL COLLEGE OF PHYSICIANS OF EDINBURGH, HONORARY MEMBER OF THE IMPERIAL MEDICO-CHIRURGICAL SOCIETY OF ST PETERSBURGH, HONORARY MEMBER OF THE HUNTERIAN MEDICAL SOCIETY, MEMBER OF THE MEDICO-CHIRURGICAL SOCIETY OF LONDON, FORMERLY VICE-PRESIDENT OF THE SOCIETY OF ARTS FOR SCOTLAND, AND SENIOR PRESIDENT OF THE ROYAL MEDICAL SOCIETY OF EDINBURGH.

"Domus vero accommodanda est et ad facultates, et ad sanitatem, et ad incolentium jucundum usum."

"Iis hanc maxime requirentibus, qui corporum suorum robora quieta cogitatione, nocturnaque vigilia minuerant."—CELSUS.

LONDON:
PRINTED FOR
LONGMAN, BROWN, GREEN, & LONGMANS,
PATERNOSTER-ROW.
1844.

PRINTED BY NEILL AND COMPANY, EDINBURGH.

TO THE RIGHT HONOURABLE

THE LORDS SPIRITUAL AND TEMPORAL,

AND

TO THE HONOURABLE

THE MEMBERS OF THE HOUSE OF COMMONS,

THE FOLLOWING

ILLUSTRATIONS

ARE MOST RESPECTFULLY DEDICATED,

BY THEIR VERY HUMBLE AND OBEDIENT SERVANT,

D. B. REID.

PREFACE.

THE Author of the following pages having been called upon frequently, for many years past, to give explanations on numerous points that have guided him in the varied works in which he has been engaged, has been led to entertain the opinion, that, if these were embodied in a connected series of Illustrations on the Principles and Practice of Ventilation, they would present the bearings of this subject in a form that would render them generally accessible to non-professional readers. He has also to explain, that in none of the Works hitherto executed under his directions, has he ever had the opportunity, either in Buildings or in Ships, of introducing his plans, with all the advantages of which he considers them susceptible, were they incorporated in the original design, instead of being merely appended to designs or works already executed.

In the attempts which he has made to assist in placing the Practice of Ventilation on a more precise

and systematic footing, his efforts were devoted principally, in the first place, to the amount of air required for this purpose. Hundreds of individuals were successively made the subject of experiment in the manner described afterwards, and the result led to that enlarged supply, which forms the leading feature in those peculiarities he has introduced. After the amount of air had been determined, and the extent to which the ordinary estimate ought to be varied, according to the ever-changing circumstances under which Ventilation is conducted, extreme diffusion—the ingress and egress of the air—the moving power when natural ventilation was not sufficient—the nature of the mechanical power to be employed, or the mode of applying heat when it was preferred—the plenum and vacuum impulse—the chemical examination of the air to be used—its purification when necessary—the communication of moisture—the treatment of fresh air saturated with moisture—the direct exclusion of the products from the combustion of gas-lamps and other artificial lights—the prevention of descending currents from cold glass,—and numerous other circumstances, engaged attention, each building to be ventilated having been treated as a piece of apparatus, and absolute power obtained over the ingress and egress of air, so far as the peculiarities of the case rendered this necessary or desirable.

Before the discoveries of Priestley, Scheele, Lavoisier, and Black, the term Ventilation could have had no distinct and definite meaning, such as is now attached to it. The great lineaments which it presents might

then have been unfolded, but the Chemistry of the numerous gases which have since been made known was a blank in the page of science. They too often surrounded or entered the habitations of men without being perceived, along with the more subtle malaria and contagion, as to which, though information may still be very defective, many important points have been ascertained, particularly in respect to the circumstances by which they are nourished and propagated, and the means by which they may be dissipated or destroyed. A very important discovery, also, which has thrown a new flood of light on respiration, transpiration, and the movements of gases, vapours, and gaseous emanations generally, whether simple in their compositions or loaded with impurities—one which has the most important and practical bearings on Ventilation, is so strictly modern, that it is to Dr Dalton that science is indebted for the first exposition of its nature, and to Professor Graham for that full development which has placed its practical relations in a definite form before the public.

The progress of Ventilation received a great impetus from the appointment of a Committee of the House of Commons, on Acoustics and Ventilation, in the year 1835, on the motion of Benjamin Hawes, Esq., M.P. Numerous parliamentary documents, not only connected with the Houses of Parliament, but also with other Public Buildings, with private Dwelling-Houses, and with Mines, Ships, and Manufactories, shew the extent to which it has lately formed a leading object of consideration. It constitutes one of the most im-

portant items to which the attention of the Health of Towns' Commission is directed. The various statistical and sanatory reports that have been issued from the Home Office, and from the Medical Departments of the Army and of the Navy, under the direction of Sir James M'Grigor and Sir William Burnett, add much interesting information on the same question. And, if we look to the medical profession generally, the observations of Sir James Clarke on Consumption, and on the Sanative Influence of Climate, the remarks of Dr Combe, Dr James Johnston, Dr Forbes, Dr Southwood Smith, and numerous others, and the ingenious suggestions and improvements introduced by Dr Arnott, all shew how broadly the necessity of improved Ventilation is appreciated, more especially since Tredgold had the merit of placing this subject in a more consistent position than it had ever previously presented.

But, unless the public be sufficiently informed to second the efforts that are made, so that their results shall penetrate into the habitations of individual men, a long and lingering period may elapse before Ventilation can be generally introduced to the extent that is desirable for health in ordinary dwelling-houses.

Mental anxiety may, perhaps, be considered the most powerful enemy to the duration of human life, and, next to it, defective nutriment, whether in quantity or quality. But after these, no other cause, at least in modern times, appears to have inflicted so great an amount of evil upon the human race as defective Ventilation—too often the forerunner of plagues and pesti-

lence in former times, and associated, even at present, with an immense loss of life, which is abundantly testified in Mr Chadwick's Reports and other official documents. Imperfect Ventilation supplies bad air from without; it increases within all its deleterious effects; and, if it really exert that amount of evil which has been represented, surely general education, one of the most influential of all remedies, ought to be brought to bear upon it.

The power and grandeur of Chemistry, in its relations to the arts and sciences, have been universally acknowledged, and its value in agriculture is beginning to be more generally recognized; but the great truths which it has developed, have as yet been very partially and imperfectly applied to the improvement of health—the highest, the most deeply interesting, and the most practically useful of all its applications. Chemistry has shewn that no operation of art presents such a continuous and incessant series of changes as those that take place in the living system, and are essential to all the functions of life, and affords a fair and reasonable hope, that it may be ultimately as important in increasing the duration of human life, and in improving health and strength, as it has already proved in giving man new and increased powers over all the materials of the inorganic world.

Innumerable resources have been provided by an all-bountiful Providence for ministering, perhaps indefinitely, to the necessities, as well as to the comforts of life, but many of them remain comparatively barren and un-

productive from the want of proper cultivation, while the operation of varied causes of danger, disease, and death, perpetually adding to the sufferings of man, might often be effectually prevented, were he in general to study the nature of his own frame, and of the agents with which he is surrounded. This, in conjunction with lessons on the Chemistry of daily life, would present great resources and capabilities without additional expenditure, by the new means of economy and improvement which would then become accessible to individual men. Nor is there any department of science which might not thus be brought to bear more rapidly and more effectually on the progress of art. Endless opportunities of improvement only await the skill and activity of man to be indefinitely extended and applied; but unless the key to th enature of the material world be given by some explanatory lessons on science, and especially on Chemistry, the most awakening and fundamental of all the physical sciences, the power of improvement, even in civilised nations, must remain comparatively a sealed book to a large mass of the community.

In its great and leading features, Ventilation presents no complexity as applied to individual apartments; though a deficiency of knowledge in those who conduct or manage it, often renders the most simple and valuable plans of little or no use. But in complicated structures, where many contending circumstances require adjustment, and where very limited measures only have been introduced, it is often difficult to say whether deficiency of skill in the management of the means at com-

mand, or unreasonable expectations as to the effects anticipated, when the apartments are over-crowded, may be most at fault in reference to the circumstances that may, at the moment, engage attention. It would be well were it more generally kept in recollection, that the amount of Ventilation desirable in any individual apartment, is as various as the architectural structure in which it is introduced, the numbers with which it may be crowded, the purposes to which it may be applied, the degree of comfort which may be demanded, the habits and feelings of those to whom it must be adapted, the amount of value which they may be disposed to place upon fresh air, and the condition of the external atmosphere from which the supply is to be procured.

Air must, in reality, be considered in the same light as food; and, therefore, the amount of supply, the condition in which it is introduced, and equality of distribution, are essential considerations in every well-ventilated apartment. In discussing systems of Ventilation, the amount of supply is too frequently lost sight of, though this may constitute the principal cause of expense in one plan compared with another. Again, it is often forgotten that any merely architectural arrangement, either for Ventilation or other purposes, when once finished, may be regarded as being completed for ever; but the management of Ventilation in a crowded and varying assembly, is like the management of a musical instrument, which

must not only be tuned to a proper key, but sustained continuously with an impulse apportioned to the strength and tone with which it ought to breathe.

Dr Reid is glad to have this opportunity of expressing his acknowledgments to Benjamin Hawes, Esq., M.P., the Chairman of the Committee of the House of Commons on Acoustics and Ventilation, to the Right Hon. Lord Sudeley, the Chairman of the Committee for Selecting the Designs for the New Houses of Parliament, and to the Commissioners of Her Majesty's Woods and Forests, who have continued to afford him every facility in carrying into execution the principal experiments described in this work, viz. those made in the House of Commons. These experiments might have been rendered more complete, had time permitted the adjoining apartments and passages to have been included along with the House of Commons, but this was not required for the purposes recommended by the Committee. It must not be understood, however, that nothing is done for the principal lobbies. On all occasions when they are crowded, the atmosphere is changed at intervals by establishing, through one of the minor staircases, a communication between them and the base of the ventilating shaft; every gas light, also, is effectually ventilated.

In the Chapters on the Ventilation of Ships, the Author has introduced various plans and sections illustrating the form and disposition of the different decks: a glance at these will sufficiently explain that, unless

numerous instruments or separate ventilating powers be resorted to, an arrangement that becomes more and more objectionable, in proportion as the number is increased, it is impossible to expect satisfactory Ventilation, particularly in stormy weather, without providing some of those ventilating channels which form one of the principal features of some of the arrangements he has proposed for ships.

In Mines, the introduction of larger supplies of air, shorter air courses, the use of a Lamp on the principles recommended by Dr Clanny in his Improved Lamp, the Education of the Miners, and the use of a Carbonometer, or some equivalent instrument, appear to constitute the more important points that demand attention.

In the experiments with which the Author has been recently engaged, he has had the able assistance of his friend, John Imray, Esq., A.M., Engineer, who has also been associated with him in many of the consultations with which he has latterly been occupied.

Dr Reid has only further to add, in these prefatory remarks, that if the illustrations he has given shall contribute to assist the Architect in designing—the Physician in practising—and others in regulating the atmosphere in which they live, in unison with the principles of Ventilation, he will not have to regret that he has ventured to present them in the only form in which his professional engagements have allowed him time to place

them. He trusts, however, that they will also lend their aid, however humbly, in introducing select lessons on Science in Elementary Schools, an object of as much consequence to the physical wants of man, as the elements of literature are to his moral and religious conditions, and to his daily intercourse in the ordinary affairs of life.

TABLE OF CONTENTS.

PART II.

PART III.

PART IV.

PART V.

PART VI.

PART VII.

ILLUSTRATIONS OF VENTILATION.

INTRODUCTION.

1. It has pleased the Author of Nature so to constitute man, that his body is dependent on the materials with which he is surrounded for nourishment and support, and influenced by a number of agents which never cease to modify the tone of his constitution, throughout the whole period of his existence. They not only affect his animal frame, but, from the manner in which the living spirit is associated with the corporeal tenement in which it dwells, they equally influence his mental faculties. Their just operation is essential to all the functions of life; but their undue or unequal action, if not so extreme as to cause death, may lay the foundation of bad health, and give rise to morbid impressions unfavourable to the development of power, activity, and accuracy of thought and action. Among these, heat, light, and electricity, in all their changeful and fluctuating movements, are ever modifying his sensations; at times communicating a buoyancy, elasticity, and gaiety of feeling, which he can scarcely repress, while on other occasions he becomes

10

the victim of the fatal influence which they produce upon his system.

2. But no agent exerts a more continuous power upon man than the atmosphere by which he is surrounded. There is nothing, perhaps, that presents a more wonderful combination of properties than is manifested in the endless variety of purposes which it serves, in respect to his own frame, as well as in reference to the general economy of nature. He depends upon it for the breath of life. It forms the great *pabulum vitæ*, to which all other nourishment is subordinate, and without which death immediately ensues. It is the medium of communicating to the eye the light that displays the visible creation to his view; it developes in the vital fluid that circulates in the body the warmth by which the living frame is animated; it is the medium of those vibrations, without which there would be no voice to cheer man in his present abode, no language, no melody, nor harmony of sounds; it conveys the fragrance of the most odoriferous and attractive flowers; it warns him equally, by their offensive impression, of numerous sources of disease and danger. Ten thousand rays or undulations may pass through it from the regions of space, and from the varied objects at the surface of the earth, unfolding at every point of the horizon which the eye can command, the grandeur and variety of the works of creation; and still no jarring movement is permitted to disturb the innumerable intersecting paths through which they move, or to counteract the influence which they all individually impress upon the human frame.

3. Through the medium of the air, the purer water, evaporated from the surface of the land and of the ocean, is wafted to different regions, and returned again to fertilize the soil, and quench the sufferings of thirst.

4. Again, air promotes the disintegration of all organic matter, converting, ultimately, the dead and decaying remains of animal and vegetable life into gaseous or soluble products, a large portion of which becomes diffused through the atmosphere, and serves in the course of time for the support of new generations.

Thus the very dust of the ground passes in an insensible form into the air, and is subsequently absorbed in the vicinity of the place where it may have been produced, or conveyed by aerial currents into distant lands, where it appears in a new shape, as it renews its position in the vegetable kingdom, affording, in this condition, materials which flourish for a time, and then become the subject of the same series of changes in never-ending cycles.

5. But the atmosphere is no less wonderful when viewed in the various changes which it effects in the animal and vegetable kingdom, than in the mild and genial movements which it presents on a summer's eve, or in the violent action which it assumes in the wind, the rain, and the tempest.

6. If we look to the movements of the air in the great theatre of the globe itself, we shall find it perpetually circulating between the equator and the poles, contributing much to moderate the extreme temperatures that would otherwise prevail in the torrid and polar regions, and diffusing, in all the minor streams into which it is thrown by local causes, a perpetual freshness and purity, by which the general ventilation of the different regions of the globe is maintained.

7. If we turn to man himself, nothing can afford a more useful lesson, from which we may draw the most important practical conclusions, than the examination of the relation which the human frame bears to the atmosphere by which it is surrounded. Not only does the air act continually wherever it presses upon the surface of the body; it is even brought into contact with the blood within the inmost recesses of the lungs, where its renovating action purifies this vital fluid before it returns to the heart, from which it circulates in a living stream to every part of the body, producing a never-ceasing circle of chemical changes, so long as there is life to sustain its movements. And, if we count the number of respirations made in a minute, they will be found in general to amount to twenty; so that, upon an average, we draw upon this great magazine, the atmosphere, for nourishment and

support, no less than twelve hundred times every hour during the whole period of our existence.

8. Nor has nature been more profuse in its supply of that aerial fluid with which we are surrounded, than careful in the means adopted for its efficient application. The interior surface of the minute cells of the lungs has been calculated to present an area about twenty times greater than the surface of the body; while the sanguiferous system incessantly returns the vital fluid from every part of the frame to the heart as uniformly as it is propelled, that it may again be renovated by the free draught of air which is so greedily inhaled by the lungs.

9. The external surface of the body performs functions of great importance to the maintenance of a sound and strong constitution, though they may be interrupted to a greater extent for a time than the function of the lungs, without so immediately affecting life. The operation of insensible perspiration continues without ceasing its invisible agency, unless when urged by extreme heat or other causes, into inordinate action, or suppressed by some injurious influence that tells speedily upon the constitution. The whole surface of the body is in reality penetrated with a multitude of pores, through which the air exerts a similar agency to that which proceeds with greater energy in the lungs.

10. The continuity of the action of the air is sustained in the human frame by a process no less remarkable than the extent of the arrangements for securing its full and effective influence. Not only is a powerful apparatus brought into play, by the operation of the mechanism of the chest, and the effect it produces along with the heart and bloodvessels, so as to sustain the circulation of the blood, by which, and all the varied movements connected with the function of respiration, the perfect aeration of the whole frame is effected; but these, in their turn, produce a degree of temperature in the living frame, superior, in general, to that of the atmosphere by which it is surrounded. From the change of equilibrium that necessarily ensues, the vitiated, warm, and light expanded air—expanded after it comes

in contact with the living frame, whether rejected from the lungs or from contact with the surface of the body—continually gives way to the colder and denser atmosphere which presses it upwards by a slow and gentle movement; and this being heated in its turn, is followed, in endless succession, by a perpetually renewing current throughout the whole period of existence.

11. Oxygen is the name of the principal element that comes into play in all the more peculiar effects produced by the action of the air on the living frame. It is perhaps the most interesting and important element which has been discovered. It forms one-fifth part of the air by measure, and is an agent equally singular for the extent of its distribution, and the important purposes which it serves in the general economy of the globe. It constitutes eight-ninths of the water of the globe by weight, and about one half of its more abundant solid contents, so far as has been ascertained. Few of the products of the animal and vegetable kingdoms do not contain it. No statement indeed is more literally true, than that it forms more than one-half of the materials of which the globe is composed, so far as man is yet acquainted with it. In short, it is more particularly that portion of the air which the Author of Nature has created for the more immediate support of animal and vegetable life, and for affording the means of procuring artificial heat and light by combustion.

12. If we look practically to the action of the air upon the living frame, it is impossible to contemplate the extreme importance that must necessarily be attached to the supply of air in a pure form, as indicated by the complication and extent of the provisions that have been made for this purpose, without contrasting them with the comparative indifference that is, in general, entertained by man himself as to the proper exercise of the function of respiration.

13. The knowledge of the actual existence of that invisible and attenuated air by which man is so closely surrounded, is seldom realized with that convincing consciousness of its presence which is necessary to enable him to appreciate its influence on his system. Presenting nothing gross and tangible to the exter-

nal senses, when he is defended from the more severe fluctuations of an outward atmosphere, a process of reflection becomes necessary to force this truth practically upon his attention. He may be said to have, in general, no believing faith in the real relation that subsists between his own frame and the air that he breathes. He is, accordingly, comparatively indifferent as to the nature and quality of the air that he consumes. Present to him any grosser material such as he can eat or drink, and his sensibility may be exquisite; he will descant upon such matters indefinitely on many occasions, and spare neither pains nor expense to satisfy the demands of his appetite. But the quality of that finer, more ethereal, and purer food, which has access directly and without any intervening digestive process to the living blood, is a matter of such comparative indifference, that he is too often content to breathe indefinitely the polluted atmosphere that may have previously visited a thousand lungs, so long as there is a sufficient infusion of fresh air to prevent absolute and immediate oppression, or to produce such marked effects as to awaken him more precisely to the actual position in which he is placed.

14. The standard of taste for fresh and pure atmospheric air even among those classes of society who have every luxury at command, must be considered at present as very much below what is required for health; and even where the want of it is felt and acknowledged, the amount of value placed upon it is so small and trifling, that the expense and trouble of providing proper channels for its supply are considered serious objections to its introduction. Hence, architectural arrangements have too often been considered independently of ventilation; protection from without, and stability and beauty of structure, are not the sole requisites for architectural perfection. The supply of a pure and wholesome atmosphere is essential in the adaptations required in each individual building; and so far as practical utility is taken into consideration, instead of placing the supply and regulation of air so much in the back ground, it ought, in reality, to form one of the primary features of every architectural structure in which a defence is offered from the external elements. When the air is

of inferior quality, the mental faculties are subdued and deteriorated in proportion as the body is oppressed by the vitiated atmosphere, pure air being not only essential for the proper development of the bodily frame, but also requisite for the due energy of the intellectual functions.

15. Till the discoveries of modern science revealed the nature and composition of atmospheric air, and the reciprocal action that ensues between it and the blood, the architect was, in respect to this question, like a traveller without a guide, and had no distinct appreciation of the position in which man is placed in respect to the atmospheric ocean in which he lives. And even where the facts now adverted to are known and recollected, still the rough and rude treatment to which the lungs are subjected, the vitiated atmosphere which they are so often called upon to inhale, and the transitions of atmospheric and artificial temperatures to which they are carelessly subjected, shew clearly how little the value of a mild and fresh atmosphere is practically appreciated; while the ravages of consumption, and the extended catalogue of evils accompanying diseases of the organs of respiration, point out the vast amount of misery that might be obviated, and of death that might be prevented, were the leading principles and practice of ventilation more generally understood.

16. A new era dawned upon this question when the constitution of atmospheric air was unfolded, the theory of respiration and combustion explained, the constituent elements of the corporeal frame traced more minutely in their varied movements in the living system, and the chemistry of the gases extended by the brilliant discoveries of the present age. The practical application to architecture of the truths then developed, appears to have been encompassed, however, with numerous difficulties, so that the most extreme variety of practice may still be observed, some depending upon the magnitude of the structure for the necessary supply of air, others looking to doors or windows, while, in a more limited number of examples, special channels are made for the admission of air. An unbounded field of investigation

is opened in the endless varieties of adaptations required in the details for special structures, and the nature of the ventilating power which, under different circumstances, it may be most expedient to employ. Mere variety of practice is in itself unobjectionable, as the details of ventilation are necessarily as various as the details of architectural structure. The variety of estimates as to the amount of supply have always been a leading difficulty. Perhaps no buildings have been subjected to such numerous experiments as the Houses of Parliament, to which Sir Christopher Wren, the Marquis of Chabannes, Mr Davies Gilbert, Sir Humphrey Davy, and many others, directed their attention; and it may afford some clue to the diversity of practice that has been prevalent, if it be remembered, that the area of discharge, provided by Sir Humphrey Davy, in the present House of Commons (at that time the House of Lords), was one foot; whereas at present it is fifty feet, and this is frequently worked by a power which renders it equivalent to several times that which would arise from any ordinary discharge.

17. It will be obvious indeed, that until a more general understanding shall have been entered into, as to the amount of air with which the system ought to be supplied, and the extent to which this should be placed under control, a reasonable expectation cannot be entertained that public buildings and private dwelling-houses will be much more systematically supplied with air than at present. This is the most important and primary question on which all other points depend. A false estimate as to the amount of supply required is an irreparable evil. So long as this difficulty is not specifically entered into, no suite of arrangements, however perfect in other respects, can be expected to give satisfaction. The simplicity of the arrangements required for ordinary purposes, and the difficulties connected with peculiar structures, where the architect, in indulging his professional taste, has too often taken an unbridled licence in excluding the necessary supply for the lungs, are so often imperfectly appreciated, that too frequently nothing whatever is attempted beyond the imperfect arrangements of doors and win-

dows, any thing being considered good enough for ventilation, *i. e.* for the lungs.

18. But the progress of this question will necessarily be limited to a great extent, till the public shall acquire more information on those numerous matters connected with it which have attracted so much attention of late years. Until the great elementary truths of physical science shall be introduced as essential branches of education in schools and academies, among the humblest as well as in the highest walks of life, it cannot be expected that there will be that desirable appreciation of the value of a pure and wholesome atmosphere which must ever be one of the principal objects of all who desire to advance the cause of public health. The cloud must be removed that veils at present the true state of the case from the great mass of the community.

19. The number of individuals is comparatively small who are really aware of the magnitude of the evils arising from the respiration of vitiated air. It is not generally understood that in innumerable public and private assemblies, churches, theatres, schools, &c., an atmosphere is often breathed for hours continuously which is as foul and offensive, compared with the air that is congenial to the lungs, as the water of the Thames at London Bridge contrasted with a pure mountain spring. It is no exaggerated statement to affirm, that the greatest scourge with which this and so many other climates is affected, viz. consumption, owes it origin more to ignorance of the laws of health connected with the peculiarities of exposure to alterations of air and temperature, and to the severity of local draughts, than to any disadvantages connected with the local state of the atmosphere which cannot be met with proper care and attention; that numerous other diseases, particularly catarrhs, rheumatisms, and pleurisies, often spring from this cause: that a depreciated tone of mental vigour, as well as of bodily health, may, in endless examples, be traced to the same cause; that the most deadly plagues that have ever appeared have been aggravated, if not caused, by want of cleanliness and ventilation, and that the

ordinary typhoid fever of this country almost invariably originates under similar circumstances: that hospitals imperfectly ventilated have in some cases proved a curse instead of a blessing to the miserable patients who have been conveyed to them; that public establishments are known to the medical profession, where, at one time, from the same cause, no case of compound fracture ever recovered, few or none survived the amputation of a limb; mortification attacked every wound, however trivial, while the prostration of strength became so great, that men who had at first stood the severest operations without a murmur, subsequently cried like children from the slightest pain; and that cases have actually presented themselves where the apparently lifeless corpse, subdued and oppressed far more by the atmosphere with which it was surrounded, than by the disease to which it was supposed to have fallen a victim, has actually been known to revive after removal to the dead-room, a separate apartment, where the play of a wholesome atmosphere, flowing unrestrictedly upon it, revived the fading flame of life after it was to all appearance gone, and where health and strength were ultimately restored; that the practice in hospitals has been accompanied with the most decided reduction of mortality as the ventilation has been improved: that even in cities, generally, the mortality has regularly diminished as the external ventilation of the streets has been placed on a better and more systematic footing, by increased attention to cleanliness, and by affording free channels for the passage of air.

20. But, independent of the more serious and direct attacks of disease, there are numerous minor evils that often prey upon the constitution, where the air is of inferior quality. The long-continued action of vitiated air gradually undermines the tone and strength of the stomach; the appetite diminishes, and the citadel or mainspring of the constitution being thus enfeebled or destroyed, all the other powers of the system also gradually give way. This may be observed in numerous dwelling-houses, in many varieties of shops, offices, and counting-houses, and in various trades and sedentary occupations, where the natural wants

of the system, a proper care as to regularity of diet and to exercise in the open air, are absorbed in attention to business. It would be well indeed were individuals so exposed, to pause and calculate, with a little of that keenness with which they enter upon their daily pursuits, the extent to which they are obliged to draw upon the capital of their constitution in labouring under the oppression which an inferior atmosphere always developes. Premature old age is indeed one of the most certain consequences of long exposure to a vitiated atmosphere, especially when it is accompanied by an over-anxious and harassing attention to business; and in various occupations, the short span of human life is abridged many years by this cause, independently of the low tone at which it often flows, and the endless discomfort and annoyance to which, in such cases, it is so often subjected.

21. Nor are the moral and intellectual faculties to be forgotten in considering the influence of a vitiated atmosphere, as the energy and tone of both is lowered and depressed by bad air: these are impaired as much at least as the corporeal functions, and, when not subdued by the mere force of the oppression to which they are subjected, are often forced into an unnatural state of excitement, equally incompatible with health, and with the sober exercise of the reasoning faculties.

22. Ventilation consists in the due and appropriate supply of air to any apartment, passage, or other cavity to which the external atmosphere has not free and unlimited access. It requires, accordingly, to be as various in different buildings as their architectural construction, the climate in which they are placed, the materials of which they are composed, the purposes to which they are applied, and the habits of the inmates by whom they are occupied. *External Ventilation* is a term frequently used to indicate the supply of air to streets, squares, courts, and alleys, or to any special situation or area not included by buildings, and the quality of the air as dependent on any special circumstances by which it may be affected.

23. Much of the misunderstanding that prevails, too generally, in respect to ventilation, arises from the extreme diversity of

standards which different individuals consider essential to their comfort. This evil is greatly aggravated by the different provision which is generally made for modifying the ventilation in unison with the variety of circumstances in which even the same constitution may be exposed. Ventilation requires, in all ordinary cases, to be varied from time to time, according to numerous circumstances, subject to perpetual fluctuation, which are noticed in the succeeding chapters.

24. It will be sufficiently obvious, that due and appropriate ventilation, however simple it may be in individual cases, is, in reality, in many public buildings, a very large question, more particularly in complicated structures, and cannot be successfully studied without entering on a number of different subjects, among which the most important are the following:

I. The general properties of gases.

II. The nature of atmospheric air, the changes to which it is subject, and the impurities with which it is apt to be contaminated.

III. The processes of respiration and transpiration, by which the air is brought into immediate action upon the living system, and the influence of these functions on atmospheric air.

IV. The process of combustion, and the various modes of communicating artificial warmth to the air, as the open fire—the stove—steam and hot-water apparatus.

V. The deterioration of the atmosphere by artificial illumination; the effect produced by lamps and candles.

VI. The nature of gas; the arrangements by which the strong objections to its more general introduction may be obviated.

VII. The means of securing ventilation—natural ventilation—artificial ventilation—ventilation by fire—ventilation by mechanical power—the pump, the fanner, the screw, the bellows, the windmill ventilator, &c.

In special cases, particularly in manufactories where noxious products are evolved, unless their nature, and the manner of dis-

posing of them, be understood, no certain results can be anticipated from the mode in which they are treated.

25. It will also be remarked that the nature and amount of ventilation must be modified by the extent of space to which it is applied, the numbers that may be crowded together, and the rapidity and extent of alternations to which they may be subject. In the House of Commons, where the number fluctuates continually, provision is required for 800 at one time, and in a few minutes afterwards for fifty or sixty only, or even a much smaller number, which, in a short time, may be as rapidly increased as it was diminished.

26. Again, the system of ventilation adopted frequently requires peculiar modifications from the particular circumstances in which it is applied, more especially in mines, ships, steamboats, transports, manufactories, prisons, hospitals, schools, theatres, refreshment-rooms, courts of law, hotels, dwelling-houses, coaches, stables, tunnels, and, in short, under all circumstances where the air is specially affected either by the individuals present, or the nature of the materials to which it may be exposed.

27. The necessity of ventilation to man arises from the structure of the human frame, its relation to the air with which it is surrounded, and the manner in which air generally is affected by respiration and transpiration—by many natural operations—by many of the products both of the animal and vegetable kingdom, and innumerable operations of art. These tend to vitiate the air and render it unwholesome by the evolution of noxious products, or by withdrawing that peculiar principle—oxygen—on which its power of supporting life more pre-eminently depends.

28. When the external atmosphere is pure, and the system free from disease, the air feels light and elastic, respiration is performed unconsciously, the mental faculties are serene, the bodily strength great, the appetite good, and the sleep calm and refreshing.

29. But when the air is of inferior quality, the respiration

becomes uncomfortable, and often anxious or oppressive, the strength begins to fail, the general tone of the system is depressed, the power of bodily or mental exertion becomes impaired, the sleep anxious and uncertain, and, in extreme cases, where the air has been vitiated to a great extent, death rapidly ensues. In more minute proportions, impurities in the air produce an endless variety of discomfort and disease, sometimes inducing a sense of languor or debility that may be barely recognised; while, on other occasions, they undermine the constitution by a slow and insidious action, which is too often accompanied by a permanent loss of health.

30. Purity and freshness are still more essential in the supply of atmospheric air for respiration than in that of ordinary aliments, as the air undergoes no special chemical preparation before it acts upon the system, but is transferred at once to the cells of the lungs, and there it is almost directly brought into contact with the blood, nothing intervening between them except a minute portion of the most attenuated membrane, which does not prevent their tendency to affect each other.

31. The principal object of ventilation being to supply pure air for respiration, it may be well for the reader to familiarize himself with some of the leading facts mentioned in the following paragraphs. The standard of quantities assumed is the mean of varied observation by different experimenters. Few results, however, are more various than the number of cubic inches of air respired by different individuals at the same period, or by the same individual at different periods, and hence great diversity may be expected in the result of the analysis of expired air, according as it is diluted largely with air from the mouth or nostrils, or obtained by a forced effort from the lungs after that in the larger air-passages shall have been expelled.

32. The pure air received into the lungs is always diluted with the air already there, before it acts upon the blood in the cells.

33. The inhabitants of London, amounting in number to two millions, respire, every minute, 370,370 cubic feet, or 12½ tons

of air, and consequently require, for respiration alone, 6,653,000 tons per annum. Allowing, however, 10 cubic feet per minute to each individual for the supply of his various wants, the consumption amounts to 359,000,000 of tons annually, or nearly 1,000,000 of tons daily.

34. In a room containing 1,000,000 cubic feet of air there are assembled 10,000 persons. The whole of the air will have been respired in nine hours, while an adequate supply of ten cubic feet per minute to every person would necessitate a total change every ten minutes, or a supply of fresh air amounting to 6,000,000 of cubic feet, or 205 tons per hour.

35. In a room 12 feet square and 12 feet high, containing, therefore, 1728 cubic feet of air, there are ten persons who respire the whole air in the room in 15½ hours, and require a complete change every seventeen minutes in order to supply them with 10 cubic feet per minute. Such a change might be effected by the ingress and egress of air through apertures, 1 square foot in area, at the rate of 100 feet per minute, or 1⅐ mile per hour.

36. In the same manner, in a church, 80 feet long, 50 feet wide, and 40 feet high, containing therefore 160,000 cubic feet, there may be 1000 persons. For their supply there would be required a change every sixteen minutes, or about 20 tons of fresh air every hour.

37. One man during a life of 50 years makes 525,600,000 respirations, inspires 166.3 tons of air, consumes 18.57 tons of oxygen, discharges 19.8 tons of carbonic acid from his lungs, containing 5.475 tons of carbon, or about 80 times the weight of his own body (150 lb.). Were he allowed 10 cubic feet of air per minute, he would, during 50 years, have used nearly 900 tons.

38. The inhabitants of the earth, taken at 1,000,000,000, respire annually 3,327,000,000 of tons of air, and evolve 109½ millions of tons of carbon. The total weight of the atmosphere is about 5,261,000,000,000,000 of tons, so that it would require 1,580,000 years to elapse before the whole atmosphere could be respired by the human inhabitants of earth.

39. Of the atmosphere, 78 per cent. or 4,103,600,000,000,000 tons are nitrogen, and 22 per cent. or 1,157,400,000,000,000 tons are oxygen. Of this quantity, there are annually consumed, by the human inhabitants of the globe, 371,250,000 tons of oxygen, so that it would require nearly 3,120,000 years for this supply to be exhausted, supposing respiration to be carried on till the last portions are consumed, did no principle exist by which it could be renovated. The quantity of carbon and moisture evolved every minute by one individual, by respiration alone, amounts to 3.27 grains of carbon, and 3.2 grains of watery vapour. From an assembly of 1000 persons, there would, therefore, be evolved, in one hour, 28 lb. of carbon, and 27½ lb. of water.

40. The whole inhabitants of the earth discharge annually from their lungs, 107,000,000 tons of water, a quantity which, if collected together, would form a sphere nearly 2000 feet in diameter.

41. The inhabitants of London, taken at 2,000,000, evolve annually, from their lungs, about 220,000 tons of carbon, and 215,000 tons of water.

42. At a sitting of the House of Commons on a very leading question, when 800 persons, members and strangers, are present for twelve hours, air is required for 11,520,000 respirations.

20	= respirations by one person in one minute.
60	= minutes per hour.
1200	= respirations per hour.
12	= hours of sitting.
14400	= respirations per 12 hours.
800	= number of members and strangers present.
11,520,000	= number of respirations made by 800 persons in twelve hours.

43. It has been found, that a man makes, on an average, 20 respirations per minute, and that at each respiration he inhales 16 cubic inches of air.

It may be assumed that he consumes oxygen amounting to 10 per cent. by volume, of the air inspired, and discharges about

7.8 per cent. of carbonic acid gas. The accordance of those numbers, with the mean of estimates given by the authorities cited, will appear from the annexed table.

Authorities.	Oxygen consumed.	Carbonic Acid discharged.
Dr Thomson, . . .	...	3.72 per cent.
Allan and Pepys, . .	...	8.125 ...
Sir H. Davy, . . .	9.875 per cent.	6.875 ...
Lavoisier and Seguin,	12.940 ...	4.200 ...
Menzies, ...	11.320 ...	...
Coathupe and Liebig,	...	7.750 ...

44. On the whole, it may be stated,* that, for 320 cubic inches of air inhaled per minute, there are consumed 32 cubic inches of oxygen, and there are discharged 25 cubic inches of carbonic acid gas. And on these numbers the following table has been drawn out.

45. The weight of the gases has been calculated from the volume given and the specific gravity, and the weight of carbon evolved is to that of carbonic acid discharged as 6.12 is to 22.12, the numbers expressing the atomic equivalents of those bodies. Out of the 22.12 parts by weight of carbonic acid, 6.12 being carbon, the remaining 16 parts are oxygen, a proportion which leads to the 10th column of the table. The 11th column is found by subtracting the weight of oxygen combining with carbon, so as to produce carbonic acid, from the total weight of oxygen consumed; and therefore expresses the amount of oxygen retained in the body, or discharged in combination with hydrogen, producing watery vapour. The weight of watery vapour, in the last column, is that which is due to the saturation of the given volume of expired air at the average temperature of 98°, and is about the 1-100th part of a grain per cubic inch.

* This can only be taken as an approximation. The extreme diversity of the results obtained under different circumstances, shews that nothing can be expected to lead to a proper generalization, except a much more extensive and minute series of experiments than has hitherto been conducted.

Table of the Amount of Air Respired and Products evolved in given times, by one individual.

Time.	No. of Respirations.	Air Inhaled.		Oxygen consumed.		Carbonic Acid discharged.		Carbon evolved. Weight.	Oxygen in Carbonic Acid. Weight.	Oxygen. Unaccounted for Weight.	Watery Vapour. Weight.
		Volume.	Weight.	Volume.	Weight.	Volume.	Weight.				
3 seconds,	1	Cub. In. 16	Gr. 4.96	Cub. In. 1.6	Gr. 0.547	Cub. In. 1.25	Gr. 0.59	Gr. 0.163	Gr. 0.427	Gr. 0.12	Gr. 0.16
1 minute,	20	320	99.24	32.0	10.940	25.00	11.82	3.270	8.550	2.40	3.20
1 hour,	1,200	Cub. Ft. 11.1	5954.25	Cub. Ft. 1.1	656.450	1500.00	709.25	196.230	513.020	143.43	192.00
1 day,	28,800	266.6	Lb. 20.4	27	Lb. 2.265	Cub. Ft. 20.83	Lb. 2.43	Lb. 0.6723	Lb. 1.76	Lb. 0.5	Lb. 0.658
1 year,	10,512,000	97,333.3	7451.3	9733	821.600	7604.16	887.30	245.5000	641.80	179.80	240.28
50 years,	525,600,000	4,866,666.6	Tons. 166.3	486,666	Tons. 18.34	380,208.00	Tons. 19.80	Tons. 5.478	Tons. 14.32	Tons. 4.02	Tons. 5.37

PART I.

PRELIMINARY REMARKS ON THE IMPROVEMENT OF HEALTH.

CHAPTER I.

INTRODUCTION OF SELECT LESSONS ON SCIENCE IN ELEMENTARY SCHOOLS.

46. Every one who has cast even the most transient glance at the statistical returns that have developed the relative value, or duration of different conditions of human life, must see that its average worth is very considerably below the standard of expectation, which a proper attention to the means of preserving health would justify. To what extent the powers of the human constitution may enable life to be prolonged, and health and strength to be sustained, by providing for the various wants which its relation to external agents demands, it would be impossible to define by any very precise and accurate line. But if we look to the facts pointed out by modern chemistry and physiology in reference to the human frame, and contrast the provisions which the Creator has made for giving it power and endurance, with the extent to which these are too often counteracted by ignorance, or inattention to the laws of life, or by the reckless and careless indifference with which health and life

are exposed, it is not affirming too much to say, that a great addition to its length and to comfort might be reasonably anticipated in all classes of society, were the laws that regulate it generally understood, and applied to the circumstances of daily life.

47. An honoured age of eighty, ninety, or a hundred years might then be expected to become the average standard of human life, instead of the exception, as it is at present. Cities and country villages would emulate each other in showing a population whose health and strength would give grace and dignity to human nature. Some breathing time would be afforded for contemplation, and for the cultivation both of mind and body. A whole population passing through a hurried, a wretched, and an ephemeral existence, would not so frequently count its victims by thousands and tens of thousands who are often, with much truth, represented as being born only to die again, and every class of society would attain a higher standard or tone in all the great relations by which humanity is encircled.

48. Results such as these could not spring from any single cause: the power of religion, the assistance of legislation, and the more general enlistment of all the sympathies of human nature, in favour of elevation of character, even among the humblest and most degraded of society, must engage more attention, as the most interesting and important of all occupations, independently of the mere alleviation of those physical wants and evils to which humanity is subject. Nor can any other measures be expected to penetrate into individual habitations, or awaken that cordial understanding between different ranks of life, the interruption to which, wherever it occurs, must ever be considered one of the greatest misfortunes to which society is liable, from the extent to which it paralyses all efforts for amelioration.

49. But, without adverting more particularly to questions that could not be discussed here without entering into details, the length of which would be incompatible with the more specific objects of this work, it may be observed that Γνωθι σεαυτον may

be justly applied to the necessity of a knowledge of the physical laws of life, as the only sure basis of improving the physical man, in the same manner as self-knowledge is indispensable to the improvement of the soul.

50. The association, accordingly, of proper means of communicating a knowledge of the great elementary truths of science, so far as they bear on the affairs of daily life, with the ordinary means of education, is considered the principal desideratum for enabling more specific information to be acquired by all classes of society on the relations of the human frame to the external world, on the evils to which it is too often subjected, and on the advantages which would result from the adoption of measures by which they might be avoided; and if, for many years, I have, at such leisure hours as my professional engagements permitted, given numerons courses on the chemistry of daily life to schoolmasters and young persons, such as I gave lately to a thousand teachers in Exeter Hall, under the sanction of the Committee of the Privy Council on Education, and joined with those who have advocated such measures, both in theory and practice, it has been from the conviction that it cannot otherwise be expected to attain those objects which the progress of science, as well as the wants of human nature, point out, by equally convincing evidence, as links of the great chain unfolded by the natural progress of society.

51. I think I may now be permitted to say, that I have ascertained, by the courses referred to, and by numerous inquiries made in England, Scotland, and Ireland, that, were the questions taken up on a great scale, an expense of from five to seven hundred pounds per annum, continued for a limited period, would soon enable missionary teachers to traverse the whole kingdom, and teach schoolmasters, who may not have had other opportunities, the great elementary truths that bear on health and length of life, enabling them not only to apply many of these in their own schools, but also to become the medium of introducing them to their pupils, and, through them, gradually to the whole community, were they to give familiar explanations, and simple experi-

mental illustrations, once a week, of the facts which they would be taught. In the chemical department, the great barrier to such progress in some schools has been the attempt of the master to use complicated apparatus without adequate instruction. Let him content himself with plain apparatus, such as may be purchased for one or two pounds, or even with nothing more than a bottle, a bent tube, a few jars, and such materials as are every where accessible in civilized countries, and then, if a proper selection of experiments shall have been pointed out, he will find that he has the means of thousands of illustrations in which his pupils will delight—to which they will run from their play—and which will present endless topics of interesting conversation both at home and abroad.

52. And should any one say that I entertain too sanguine anticipations, or that this question is urged too strongly, I would reply, in the *first* place, that the views I have expressed do not exceed those realities which occasionally appear, notwithstanding all the multiplied disadvantages with which they have been surrounded.

53. *Secondly*, An examination into the history of many cases of longevity, of health and strength, and of the influence of early training, where health was considered the primary object, has equally assured me that any calm and unbiassed enquiry will shew, that the expectations entertained are not unreasonable, but present a proper standard for aspiring to, though years or generations in some cases may elapse before they are attained, where the constitution may have been greatly impaired.

54. *Thirdly*, The scenes which I have witnessed during the last six-and-twenty years in chemical works in which I have been engaged, sometimes for many months continuously—in lanes, courts, and closes in Edinburgh, in which I attended to Dispensary practice while a student of medicine—in a fever hospital with 170 patients, where I resided during a severe epidemic—in numerous manufactories, mines, and ships—and in all classes of public buildings in this country, and on the continent—have imp d me more and more strongly, on each succeeding occa-

sion, with the conviction that no other means would be at all adequate to cope with the magnitude of the evils it is desirable to remove, and to place measures for health on an extensive, consistent, economical, and practical basis.

55. The following extract is taken from a pamphlet on the study of Chemistry, in which the importance of conjoining the study of the alphabet of nature and of science, with the ordinary branches of education in elementary schools, was advocated in explaining the nature of the course given at Exeter Hall. The reader is referred to this pamphlet, if he should desire more minute statements than can be given here on this question.

The benefits arising from such a course would be—

I. A practical knowledge of some of the most important laws affecting health.

II. A practical knowledge of ventilation, and of the means, in many cases equally simple and economical, by which the more oppressive evils of a vitiated atmosphere may be removed.

III. A knowledge of the more important elements of which the material world is composed; of their action upon each other, and upon the human frame. The key that would thus be given in early life to the works of nature and the operations of art, would necessarily have the following advantages:—

1. The lessons given, though few in number, would be equivalent to a great and extended course, when multiplied, after a few years, by the experience of daily life in those objects to which they are directed.

2. The knowledge they would impart being in reference to materials, the nature, use, and adaptation of which to various purposes form the occupation of the great mass of mankind, great improvements in Agriculture, Architecture, Medicine, Engineering, and in short, in every branch of Art or Science, would ensue, from the more extensive and familiar knowledge that would then be acquired, by all classes of society, in reference to the nature of the material world.

3. The standard of professional science among those more immediately occupied in professional pursuits would be advanced.

as there would then be an opportunity of training the eye and the ear to observation, and the hand to manipulation, in early life; without these, however much the intellect may be trained, it is impossible to educate so accomplished observers, or such accurate experimenters in science. Elementary instruction in science has, in other respects also, become essential for young persons intended for professions where a knowledge of physical science is necessary; as, from the great progress now made in all its branches, it would be as impossible to expect the medical man, the engineer, the architect, the manufacturer, and all who are interested in science, to obtain that amount of information from the usual course of education which is now required, without some previous training in elementary schools, as it would be for any one to attain a proper rank as a scholar or a mathematician, were he never to enter upon the study of classics or mathematics, till he should join a university. Even now, in some professions, it is observed that the period of professional education is not adapted to the present state of science; and if elementary instruction, in some branches, at least, be not provided systematically in schools and academies, an extended period must be allotted to it at a future time, which would bear heavily on the means and resources of the advanced student. But if this course be omitted, college and university courses must be kept at a low par, compared with the ground they would take were professors not compelled, as they too often are, at present, to begin their courses with the most simple and elementary facts, which might be taught more advantageously before the pupils come to them.

4. The resources of the rich, the means of the poor, and the comforts of both would necessarily be increased, by the greater power that would be acquired in the production of agricultural and manufactured articles, as well as by increased economy and comfort in their use.

5. It would give the pupils a new and more expanded view of the works of the Creator, and open to their notice innumerable sources of observation, which would tend materially, in cer-

tain classes of society, to prevent the power and influence of dissipation, which, it is believed, is frequently commenced, not so much from the attractions it presents, as from individuals having no other interesting means of occupation, when not engaged in their daily pursuits.

CHAPTER II.

GENERAL CONSIDERATIONS.

56. The extreme extent to which disease, suffering, and death are produced by bad air, and by offensive draughts and currents, is well known in the medical profession; but the leading circumstances pointed out have not yet engaged that general attention which the importance of the subject demands, more especially because a correct and acknowledged value has not been put on the power of the human constitution. Every one, accordingly, appeals, in general, to the common course of events, and the standard of life around him, forgetful of the vast field of information that pneumatic chemistry and physiology have developed within the last fifty years ; and that facts have been pointed out, which, if turned as profitably to account by man in promoting health, as they have been in advancing the arts and manufactures, might reasonably be expected to be accompanied by results of equal magnitude and importance.

57. Again, every one who has traced the insidious progress of that disease which counts its weekly victims in the metropolis alone by hundreds, is impressed with the power and influence exerted by impure and overheated atmospheres, particularly when the constitution is tried alternately with them, and noxious draughts or local currents. Sir James Clarke remarks, in his work on the sanative influence of Climate, in referring to the causes of Pulmonary Consumption,—" Exciting Causes. Whatever deteriorates the health may lead to tuberculous

cachexy;* residence in a low, damp, and chilly atmosphere; long confinement to close, ill-ventilated rooms, whether nurseries, school-rooms, or manufactories; deficient exercise in the open air; improper food, either deficient in quantity or of innutritious quality; or the habitual use of an over-stimulating diet. In short, imperfect digestion and assimilation may induce tuberculous cachexy; and the earlier in life these causes are applied, the more rapidly, in general, will their effects be manifested. The offspring of the healthiest parents may thus become tuberculous in early life, if long exposed to the exciting causes enumerated." In another part of the same work, in referring to the ventilation and construction of houses, Sir James Clarke remarks,—" Nothing, indeed, can be constructed on a worse principle than the bed-rooms in this country generally are. Their small size and their lowness render them very insalubrious, unless well ventilated; and the case is rendered worse by the close windows, and by the thick curtains with which the beds are so carefully surrounded, as if to prevent the possibility of the air being renewed. The consequence is, that the occupants are breathing vitiated air during the greater part of the night; that is, during almost one-half of their lives." This statement expresses no more than the actual facts of the case; and surely such extensive evils are only to be counteracted by the united exertions of numbers, and the progress of general education.

58. If we look to fevers and inflammations, how numerous are the sources of death that might also be avoided by external cleansing, removing one of the most frequent causes of disease communicated by a vitiated atmosphere, and by attention to a more regulated atmosphere in dwelling-houses and public buildings, which would prevent the constitution from being subjected to sudden and unexpected transitions of temperature, still more dangerous to many than an impure atmosphere.

* Tuberculous cachexy is defined to be that morbid state of health which precedes, and, in fact, constitutes, the essential predisposing cause of pulmonary consumption.

59. How numerous, also, are the deaths that arise from the want of precaution in following out many of the varied occupations that engage attention, where a little hint given to the intelligent workman would enable him to avoid the first attacks of disease, and preserve his constitution amidst the dangers with which he is surrounded. How many, also, are there who, though not exposed to deleterious fumes in manufacturing operations, lose successively their strength, their appetite, and their health, in a subduing and oppressive atmosphere, of whose action they are comparatively unconscious, till its severe inroads announce a breaking up of the constitution.

60. In special circumstances, particularly on board ship, for example, where the sailor sleeps in a vitiated atmosphere, and is peculiarly exposed to fluctuations of temperature, premature old age often insidiously advances, as the appearance generally indicates, notwithstanding the high tone of health which a hardy life may for a time sustain. Dr Wilson, in his very able statistical report on the health of the Navy, makes the following remarks in reference to the position of the sailor when asleep,—a subject that will be taken up particularly at a future period, in the chapters on the Ventilation of Ships; but does not appear to entertain the opinion, that bad air, from respiration alone, is so injurious as many represent it.

"*The effect is to bring the bodies of the men into contact* in greater or less number, according to the size of the ships. When at sea, with a watch on deck, the accumulation and pressure are reduced by a half; but when in secure harbours, five hundred men, perhaps, sleep on one deck, their bodies touching each other, over the whole space laterally, and with very little spare room lengthways. The direct results of elevated temperature and deteriorated air, may be conceived; but it is not easy to conceive the amount of the first, nor the depressing and debilitating power of both, as measured by sensation, within the tropics. The tendency of such a state of things must be to subvert health, and lay the subject of it open to attacks of serious disease. It conduces to catarrhal and other simply atmospheric affections,

but it does not appear to act so prejudicially to life, other elements of health being abundant, as might be supposed. Such is the conclusion to which the following tables lead; alone, it has little, if any, appreciable influence; but let it co-operate with other agencies injurious to health, such as defective nutriment, depressing passions, or malaria, and its power may become destructively great. The salubrious influence of abundance of fresh air cannot be doubted, nor, conversely, the direct detriment to be sustained by any considerable and continued privation of it; still, the health now enjoyed by seamen, considered in connection with the necessary crowding of their sleeping-berths, and the means available for their ventilation, shews that air may be contaminated to a certain extent, for a considerable period, without producing any decidedly deleterious effect, immediate or remote, on the persons breathing it."—*Report on the Health of the Navy, by Dr Wilson.*

61. I have quoted this passage in full, as, while I fully concur with Dr Wilson as to the tendency of such a state of things to subvert health, to render the subject of it prone to serious disease, and to conduce also to catarrhal and other simply atmospheric affections, every thing which I have seen, whether in mines, manufactories, or private dwellings, or in such more limited opportunities as I have had of observing the condition of the common sailor at sea, impresses me with the conviction, that the length of life is always shortened, and the high tone of health and strength materially reduced by inspiration, for a considerable period, of air contaminated to the extent I have generally observed it in the lower deck of a man-of-war, though no special disease may be induced at the moment, or during the period that the common sailor is usually afloat, when other circumstances are favourable for his health.

SECT. I.—*Habitations of the Rich and of the Poor.*

62. The habitations of the rich suffer, in general, more from the gaseous products of their kitchens, drains, sculleries, and

smoky chimneys, being drawn into their halls and passages, and from these into their individual apartments, than from any other cause. Where channels for the supply of fresh air, and the egress of vitiated air, are not provided, many of the evils, explained in the chapters entitled Illustrations of Ventilation, must necessarily be observed.

63. Another great cause of oppression in the habitations of the rich, where the ventilation is imperfect, arises from excessive illumination. Those who are fond of a brilliant light at night, would do well to restrict it within their means of ventilation, unless they are prepared for an oppressive atmosphere, which too often induces severe headache or languor, altogether incompatible with health.

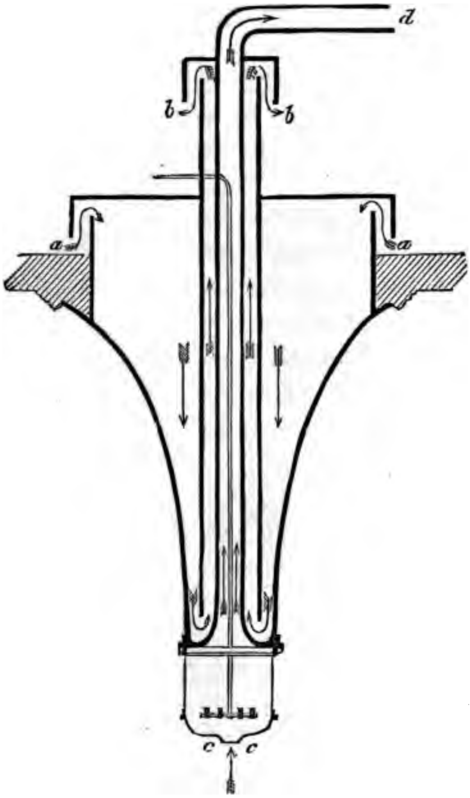
64. Where gas-lights are much used, the atmosphere too generally acquires a soporific character to many constitutions in a very short time. The accompanying Figs. 1 and 2 illus-

Fig. 1.

trate the form, and details, of the ventilation of one of the exclusive gas-burners I have used, which are explained more particularly in the chapters on Gas-Lights, and on the House of Commons. Fig. 1 indicates the appearance it presents, which may be modified indefinitely; in Fig. 2, *a* points out fresh air

entering, and, cooling the vitiated air-tube, escaping afterwards at *b*; *c c* indicate the fresh air entering to supply the burner,

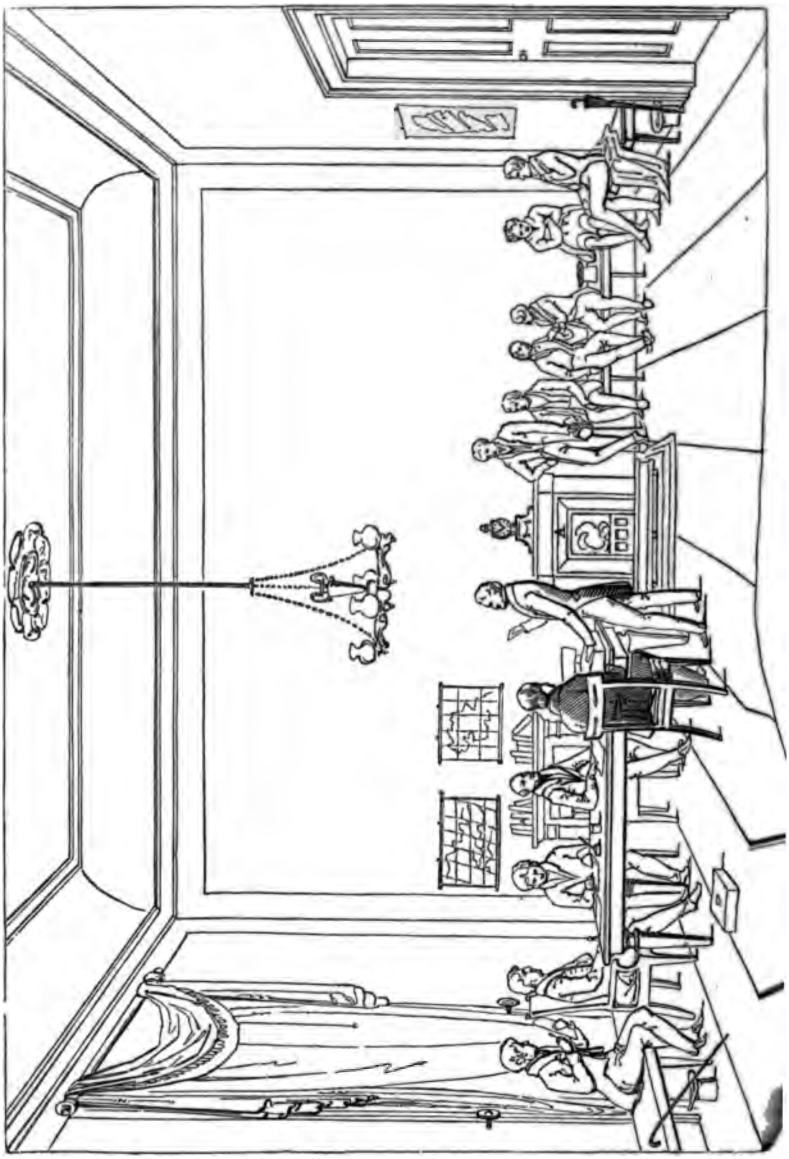
Fig. 2.



the products of combustion being carried entirely out of the apartment.

Fig. 3 explains the usual appearance of apartments that may be termed SOPORIFIC ROOMS, from the extent to which the system is usually overpowered by the excessive amount of the products of combustion from the gas. The sketch is from an apartment sometimes crowded, and, on other occasions, attended only by a few individuals. No bad air escaping above the level of the low fire-place, the upper part of such rooms is often ex-

Fig. 3.



tremely oppressive. The movement of the air is illustrated in Fig. 178.

65. The air is equally bad in innumerable shops, counting rooms, and other places where the principal heat is produced by the body, or by the common gas-lamps in use.

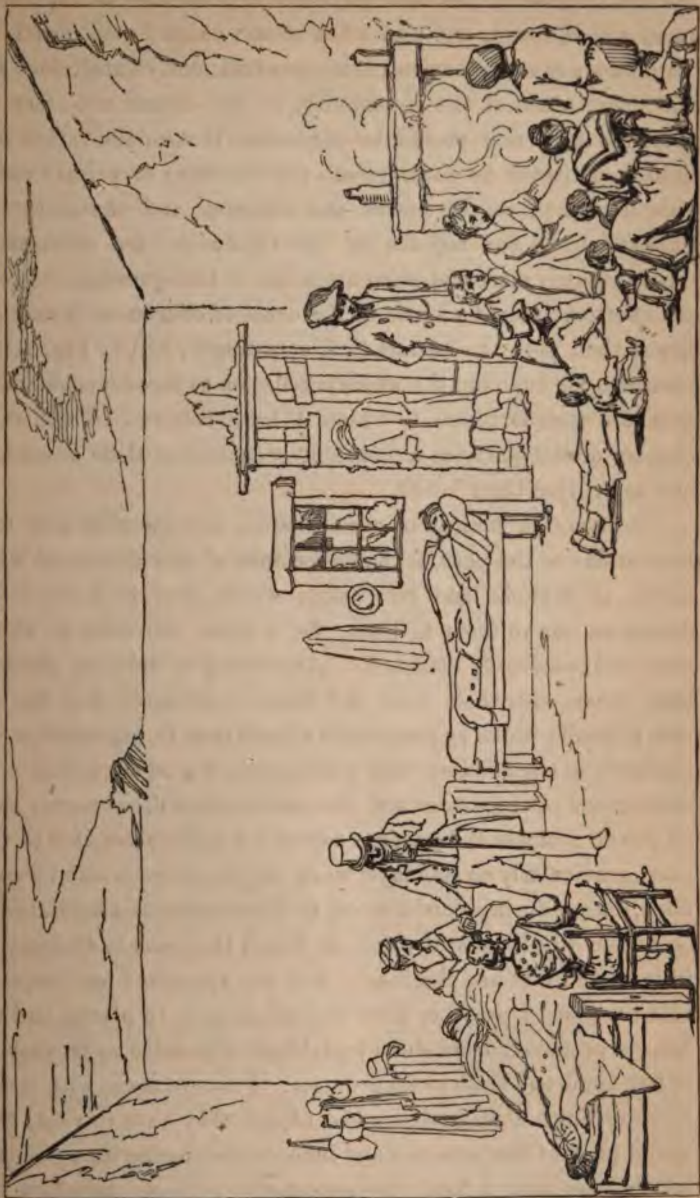
66. The ventilation of the dwellings of those whose station places them more or less above the wants of any of the common necessaries of life, is in general extremely various, according to the occupations in which they are engaged, the habits in which they indulge, and the local circumstances with which they are surrounded. Openings for the admission of air, and for its egress, controlled by valves, sufficiently protected from the influence of external currents, and capable of being used in any required proportion, would give great relief, particularly where the halls, stair-cases, and passages, are freely and largely supplied with a mild and warm atmosphere. But, unless a proper proportion be maintained between the supply and discharge, and allowance made for the large openings required to supply ordinary fireplaces, where this has not been corrected by special arrangements, many of the evils represented in the chapters describing illustrations of ventilation are apt to occur. In no cases would a few elementary lessons on ventilation tell with greater effect than in this class of dwellings; but without the means of introducing them generally, it is not to be expected that its value, or the power of using ventilation satisfactorily, will be understood to the extent that is desirable for health and comfort.

67. The dwellings of the extremely poor present scenes of misery, desolation, and woe, which it is afflicting to witness, where the sensibilities are not hardened against the sufferings of humanity. They must be seen to be understood, and to draw out that amount of individual sympathy which they imperiously demand in a civilized and christian community. The station of this country in arts, literature, and science is acknowledged throughout the globe, as well as its naval, its military, and its commercial power, and, latterly, its exertions against the slave-trade, have given a noble example in the cause of humanity, and soften the recollections of former times. But the regeneration of

its own population, or rather the placing of them in that condition which the progress of religion and philanthropy demands, is perhaps a task of more moral grandeur, and of still more difficult execution, than any other which it has attempted. Though distress may have prevailed latterly to an extent unknown in former times, the experience of the last six-and-twenty years has assured me, that the condition of the extremely poor, during that period, had it been as minutely inquired into as the peace of more recent years has permitted, would have presented abundant evidence of the necessity that had existed for society being more thoroughly awakened to their position. The annexed sketch, Fig. 4, represents merely one of numerous parallel scenes which I was in the habit of visiting as a student of medicine at Edinburgh, twenty-four years ago, in company with the medical attendant from the Dispensary. It represents a lodging-house in a close in the Cowgate, near the Grassmarket. The miserable, narrow, and undrained close, produced an offensive atmosphere on every side. The sunk floor, soft, unpaved, and unequal, gave out a damp and unwholesome smell; the patients breathed an atmosphere loaded with smoke, except where proximity to the door and window produced local and offensive draughts, and the unhappy children were grouped round a wretched fire, where it was difficult to say whether they suffered more from hunger or cold. Three beds are not shewn in the sketch, that the general disposition of that which has been described may be better understood. At night or morning, from ten to twenty, were usually around the fire; each family of four or five had a bed; and those who could not get a place in the bed, rested wherever they could lie down. In another place, I have seen five beds occupied, each with one or more sick persons, and no one to attend to their wants, or those of the infant children exposed in the midst of severe and appalling misery.

68. Since that period, the innumerable scenes of extreme poverty, wretchedness, and distress which I have seen in all parts of the country, making allowance for the varied imposture and fraud that so often simulate want, lead me, again and again, to repeat, if necessary, that a living and awakening belief of the

Fig. 4.



amount of poverty and distress which is presented in the habitations of the poor, and which has always existed with varied intermissions or exacerbations, is not yet sufficiently entertained by the great mass of the community, to the extent necessary to meet the evils that should be corrected, though the varied inquiries instituted by government, the exertions of private individuals, and of public boards and societies, and the extensive publication of the reports by Mr Chadwick, are necessarily directing daily more and more attention to this question. From the exertions recently made in the cause of education, it may be hoped that, with the labours thus encouraged, will be associated measures for enabling the whole population to become acquainted with the various topics to which I have referred in the first chapter of this part, as a means of economising their resources and improving their health.

69. Another subject of consideration in connexion with the habitations of the poor, is the importance of providing them with means of exercise and recreation, which shall hold some inducement out to them to leave, for a time, the dens to which many are too closely attached. Any means of inducing them to leave these, with their wives and families, and meet their fellow-men in public walks or gardens, is a great step to improvement in the more extreme cases; and few can have traced the influence of such means of enjoyment and recreation who will not regret that all public grounds and gardens cannot be made accessible to the poor, particularly on Sundays, when they must otherwise be confined, except during church hours, to their comfortless habitations, or driven to places still worse, in which they isolate themselves from their wives and families. Let the appointed and respectable missionary preacher have free access to such places, and let him be protected from those individuals who have so frequently of late disturbed them in their duties. I cannot agree with those, however much I may admire the object they have in view, who would prevent that cheerful and innocent recreation on a Sunday, which gives many a family the opportunity of being united on the only occasion on which they can meet together, without inter-

rupting that time which should be devoted to the public ordinances of religion.

70. Again, even the occasional amusements of the humbler classes may now perhaps demand more serious attention than they have hitherto received. The endless ball-rooms of the most degraded class, where every one is in a state of intoxication—the taverns, with drinking parties, and organs playing alternately light airs and psalm tunes—the petty theatres where the law is evaded, and young children introduced, at a cost of a penny, to scenes that steal away all sense of decency—the silent drinking rooms, where the same individuals meet, night after night, to drink or smoke, without almost even interchanging a word—and numerous other meetings which might be noted, all concur in shewing that something should be done, if possible, to give a more healthy tone and character to the occupation of their leisure hours. And surely the discoveries of science present an unbounded field of instructive amusement, which might be advantageously introduced among the humblest ranks of life, all experience having shewn that those who have had the opportunity have been interested in scientific expositions. But it has not yet been tried with those in lower stations than the ingenious mechanic; and if every human being is considered within the pale of that knowledge which explains revealed truth, who is not worthy of being taught the nature of those works of creation, which minister to his daily wants, and open to him many sources of reflection and improvement that may elevate his character, as much, in proportion, as they have benefited higher classes of society, among whom so great changes have been effected within the last fifty or sixty years, in accomplishing which the interests of popular science and literature cannot be overlooked.

71. Farther, no trials have been made in this country, either in museums, galleries of pictures, or expositions of art and national industry, that have not wiped away the notion which many had entertained, that the people in this country could not be permitted with impunity to have access to objects of art; and, while the elevation of the character of the population must

ever form the most important objects of national attention, it is admitted that few things contribute more powerfully to this effect than encouraging a taste for art, even among the humblest classes. I was much impressed with a remark of Councillor Beuth at Berlin, who, in pointing out numerous casts of antique busts in one of the practical schools, stated, "We do not wish or expect tradesmen to become sculptors, or to leave their ordinary occupations for the fine arts; but these beautiful models, ever before them, and meeting them wherever they turn, refine and elevate their taste, and lead them insensibly almost to superior, more beautiful, and more valuable workmanship."

72. I have been led to these remarks in connection with the habitations of the poor in this country, in the belief that general instruction in the elements of science would not only accomplish the purposes referred to in Chapter I., Part I., but also afford a fertile and neutral field, in the cultivation of which all parties might meet, with the view of promoting knowledge that could not fail to convey increased health, strength, and length of life to the whole community. I must refer to succeeding paragraphs for illustrations of the importance of communicating to all a knowledge of the most important facts explained by chemistry.

73. After the preceding observations, the following remarks will be sufficient, in this place, with respect to the habitations of the poor:—

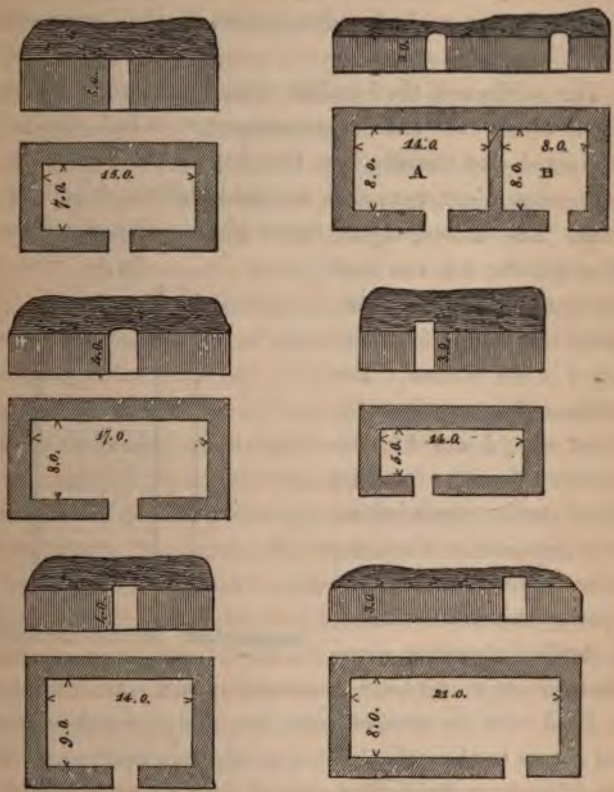
1. In the lowest class of habitations, such as are indicated in Fig. 5, there is neither window, fire-place, nor chimney, yet these are inhabited by two to eight or more human beings. The dimensions shewn were supplied by my friend Mr Lane.

2. Ventilation need not be expected where food, fuel, and clothing are deficient. Heat is still more essential to the human frame than fresh air, which consumes the body by slow combustion or oxygenation, when food is not supplied. Defective ilation reduces the oxygenation, preserves warmth, stupefies . and allays the pangs of hunger.

ventilation, reducing the power of oxygenating

the blood, and of sustaining temperature, produces a morbid condition which diminishes the relish and power of digesting plain

Fig. 5.



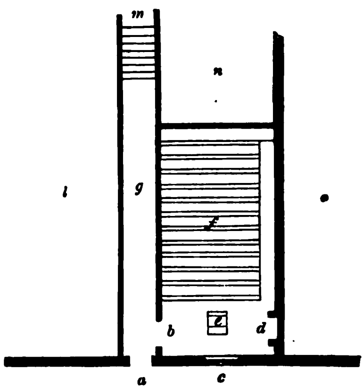
and wholesome food. Unnatural stimuli, such as ardent spirits and opium, are required to excite the languid circulation, and make it feel, though only temporarily, that vigour of circulation which gives animation and vivacity to the intellect, as well as strength to the body.

4. The actual state of the atmosphere, in the habitations of the extremely poor, is too bad and too revolting to be understood by any except those who actually visit them. There are unquestionably many exceptions, but in general, external cleansing, and an improved condition in their means and habits are essential, before

any decided improvements can be extensively introduced. If draughts and currents are offensive to all, there are few who are more sensitively alive to them than those whose hunger, want of clothing, and want of fuel, reduces them to the lowest scale of misery.

5. The children of the humbler classes are frequently placed in schools where the vitiated atmosphere is so bad, that it may be considered questionable how far they would benefit on the whole by going there, were they not subjected to air equally bad at home. The accompanying figure gives a plan of a school in St Giles parish; *a* is the door leading to the street, *b* the entrance to the school from the passage *g*, *c* the window, *d* the fire-place, *e* the master's desk, (the first time I saw him he spoke with difficulty; from the effects of the fire, the window, and door, he was often six weeks at a time unwell with cold, but still persevered in his duties), *f* the benches where the young children sat in a mephitic atmosphere, *m* a stair leading to a cellar filled with the most offensive impurities, which constantly gained access to the school, *l n o* contiguous apartments which hemmed in on every side that part of the class-room occupied by the boys. All fresh air entering by *b* or *c*, passed principally to the fire-place *d*.

Fig. 5.



SECT. II.—*General state of the Atmosphere in Public Buildings—Illustration from Churches.*

74. The total want of any systematic means for regulating the ingress and egress of air in the greater number of public buildings constructed, till within a comparatively recent period, renders them, in general, subject to great defects, especially when they are crowded. It cannot be expected that they will be put

upon a proper footing, till ventilation shall be considered in the original design of such structures, and provided for accordingly. In the following chapters, varied illustrations are given which will explain the leading defects to which they are liable. In this section, the condition of the air in ill ventilated churches is selected as an example with the view of illustrating the more important bearings of the question.

75. Were the ventilation of churches, placed generally upon a proper footing, this measure would not only be extremely beneficial in the direct results that would be produced, but tend powerfully, by the weekly demonstration which it would present, to extend a knowledge of the practicability and importance of the universal introduction of simple and economical arrangements for ensuring ventilation.

76. No buildings, on an average, are more deficient in the means of ventilation than churches. Air loaded with carbonic acid and the moisture of the breath, and with products from the combustion of gas, oil, or candles, chilling draughts from immense surfaces of glass, inequality of heat, emanations from grave-yards, and sometimes from dead bodies under the pews,* in the very centre of the church, and in some places, as in a church visited recently by my friend Mr Imray, in the vicinity of London, the *poisonous emanations of an open charcoal chaffer or brasier*, passing directly from the corridor into the church—may all be observed producing deleterious effects.

77. Mr Pattrickson, who, with many other gentlemen, has assisted me in collecting information as to the state of the atmosphere in the churches of London, has given me details as to one where he has seen, in one day, seven persons carried out fainting, and where three or four individuals frequently may be observed in that state during hot weather. I have myself counted, on one occasion, about three hundred individuals busily engaged in

* In a church which I visited a few weeks ago in Wales, the offence in the pew in which I sat was strong and marked, and similar to that produced by the ordinary emanations of putrefaction. On inquiry, the first person to whom I addressed myself, told me, that a body had been buried under the pew, and that various other persons made remarks as to the state of the atmosphere there.

the midst of the service in trying to relieve themselves from the oppressive atmosphere with fans and handkerchiefs. Mr Blake, Mr Meade, Mr Stewart, and many others have furnished me with similar examples, though in general less marked than that to which I have so particularly referred.

78. In those churches in which I have watched the progress of the influence of vitiated air, as the service proceeded, on individuals whose constitutions were not previously rendered dead to the influence of pure air by the state of the atmosphere to which they were accustomed at home, a slight and marked flush in the countenance usually appeared in a short time; this was soon succeeded by a sense of heat and oppression, and a tendency to sleep, more or less marked according to the condition of the atmosphere, and the extent to which the attention was engaged. The soporific influence in some cases was a source of annoyance to the conclusion of the service, but was succeeded in others by a reaction. The *vis medicatrix naturæ* did not remain inactive. The pulse rose, the circulation was accelerated, the brain became stimulated, and relief was at the same time afforded by the insensible perspiration (which had been arrested by the state of the air) becoming gross and sensible. Attention could now be sustained, but headache more or less severe was the usual consequence, and liability to dangerous colds and rheumatisms, where the body was suddenly exposed to the chilling influence of the external atmosphere, while still affected in the manner described.

79. It is scarcely necessary to state that these remarks apply to very crowded and ill-ventilated churches, and more particularly to those in which there are galleries. These effects are not less certain, in general, than the chemical indications that may be obtained by an examination of the air. On one occasion, fifty specimens of air were taken by my pupils, and others who took an interest in this question, from different churches in Edinburgh, and when the action which they had on the test employed was shewn, by the exhibition of the specimens at the Royal Society, many members, at once, named the churches from which

different specimens had been taken, from their knowledge of the state of the atmosphere that generally prevailed there. Some of the specimens were taken at the morning, and others at the afternoon or evening service.

80. But, among the varied circumstances that demand attention connected with the ventilation of churches, none is more important than the provision of a purer atmosphere for those constructed with one or more galleries. In such churches, the condition of the air, when they are crowded, is too familiarly known to require any illustration. At night, particularly, when loaded with the products of respiration, and the combustion of gas, it would not be tolerated, were it not that the stimulus of the heat gives, after a time, an increased force to the circulation, which is soon followed by the relieving influence of free and copious perspiration. In a church, which I visited not long ago, the following circumstances were pointed out to the attention of the vestry.

1. There was no regular ingress for fresh air; hence, it never entered the chapel during service, except by doors and windows.

2. The severity of the currents produced, when the doors or windows were opened in cold weather, prevented them from being generally used.

3. There was no exit for vitiated air (excepting doors or windows.)

4. About fifty powerful argand gas burners were used when artificial light was required.

5. A large gallery accommodated a number of persons above.

6. The seats for a number of children from various charity schools extended around the organ, nearly to the ceiling of the church.

7. Many of the children (in the upper seats) were above all openings whatsoever, whether of doors or windows, leading to the external air.

8. There were three services daily on Sundays.

9. The vitiated air in the church, was, by the construction of an imperfectly arranged heating apparatus, draw down, when it

was in action, during the service, and returned with all its impurities to the church, in no ways improved by the effect of the high and sharp heat to which it had been exposed.

10. Twelve of the children, taken indiscriminately, six boys and six girls, were spoken to as to the influence of the atmosphere of the church upon them. It was evident, during the service, that they could not sustain their attention. But without entering into details on this point, it may be sufficient to state, that in every one of these twelve cases, the skin was suffused with a dense and clammy perspiration. When the master of the school was spoken to, he stated, that the children suffered much from the state of the atmosphere, and that they sometimes complained that they were "heart-sick," and had to be taken out to the fresh air.

81. Few spectacles are perhaps more melancholy than those presented in cases such as these. The congregation is not unfrequently placed in an atmosphere of extreme impurity, poisonous in its tendency, arresting or interfering with some of the most important functions of life to such an extent that they are occasionally suspended for a time, when a temporary death or fainting takes place. But what must the state of the mind have been, and how far was it beneficially occupied, in the devotional exercises in which it was previously engaged. The power of the clergyman is often reduced as well as the attention of the congregation. Too often he does not recognise the darkness of the physical atmosphere that, at times, oppresses all his labours, and counteracts or diminishes his usefulness, as much by the power with which it subdues his own energies, as by the careless indifference which it encourages in his congregation. At the very moment that he may be descanting on the pernicious influence of vice, and pointing out the purifying power of that moral atmosphere which should surround the heart; how often are his labours shorn of their power by the physical poison that sometimes paralyses the best intentions, the indications of which are manifest on the application of the most ordinary tests,

and whose influence might be counteracted by means equally simple and efficacious.

82. In the general disposition and arrangements of new churches, the removal of pews, the closing of all side windows, illumination by the roof, the exclusion of galleries, and the adaptation of the spire as an instrument of ventilation, have often forced themselves upon my attention as objects of great practical importance, which might be well worthy of consideration, and often introduced with such modifications as peculiar localities may require. In a church so arranged, and particularly where the communion table, at which so important a part of the service is conducted, is as conspicuously brought into view as the pulpit, many points highly conducive to devotional feeling are united. The light, whether artificial or natural, always descending from above, would be less apt to strike offensively either upon the clergyman or the congregation. The voice of the clergyman would have to be adapted to one line or level only; whereas, at present, in many churches, it is heard distinctly in one place and not in another, according to the direction which it receives. The walls being unoccupied by galleries or windows, might be advantageously decorated with paintings, or other works of art, assisting in composing the mind to the sacred duties in which it is to engage. The ventilation would become exceedingly simple, and capable of being regulated with extreme facility. These are a few of the advantages which this form of structure presents; but, in this work, it would be out of place to enter into details in considering them further, or the manner in which many apparent objections might be obviated. In such edifices, the mere packing of the greatest possible number, within the smallest possible space, ought not to be the only rule adopted even in the humblest churches. Health, and power of attention to devotional exercises, form primary considerations.

83. In ventilating old churches, the introduction of exclusive gas-lights illuminating the pulpit and the congregation, not dazzling the eyes by being placed on either side, or too near the

clergyman, and taking care that each gallery is supplied from a pure source, instead of merely using over again the vitiated air that may have ascended from below, are the more important points demanding attention after a due supply of heat and air.

84. Above all, where different consecutive services are given in one day, means should be provided for removing thoroughly the air left after each individual service, otherwise the contamination towards night becomes extreme, where no systematic ventilation is introduced.

85. The following diagrams explain generally some of the points that have now been referred to. The details required for effective ventilation in churches are similar to those necessary for other places.

Figs. 6 and 7 point out the disposition of the ingress *a* and egress *f* of air, such as have been adopted in various churches

Fig. 6.

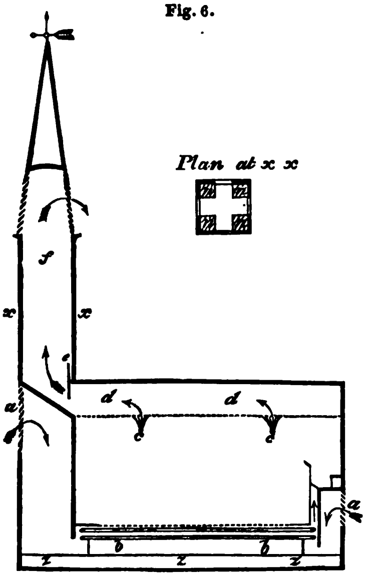
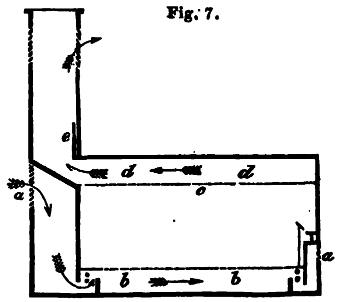


Fig. 7.



(in the church at Putney, the air is conveyed to the old tower); *b* shews an equalizing chamber for preventing the severity of draughts and currents; *e* the regulating valve, the foul air

chamber; *c c* exclusive gas-burners; *z z* non-conducting materials introduced, where the ground requires it, to prevent loss of heat; hot-water pipes are represented in different positions in the two figures. The plan at *x x* indicates the manner in which air is conveyed at the angles of the tower *n n n n*, when the central part must be opened for sound, and when the air is not permitted to escape there. The pulpits are represented larger than in reality, to shew distinctly modifications of Fig. 9.

Fig. 8 illustrates the general nature of the ventilating arrangements in the new Scotch churches; they are not, however, lighted from the roof. *a* Ingress of air; *b* equalizing chamber; *c* discharge; *e e* bell-tower and ventilating-shaft; *d d* skylight.

Fig. 8.

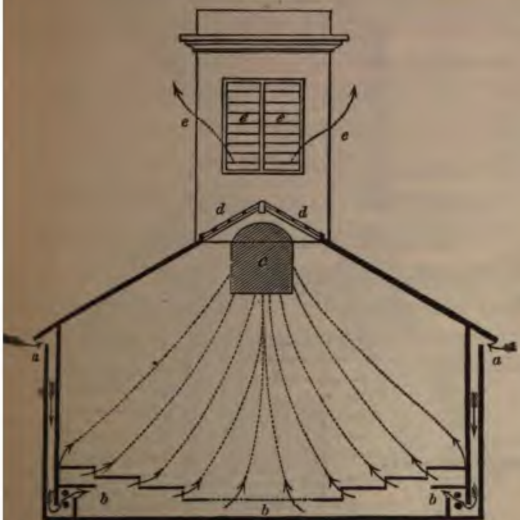
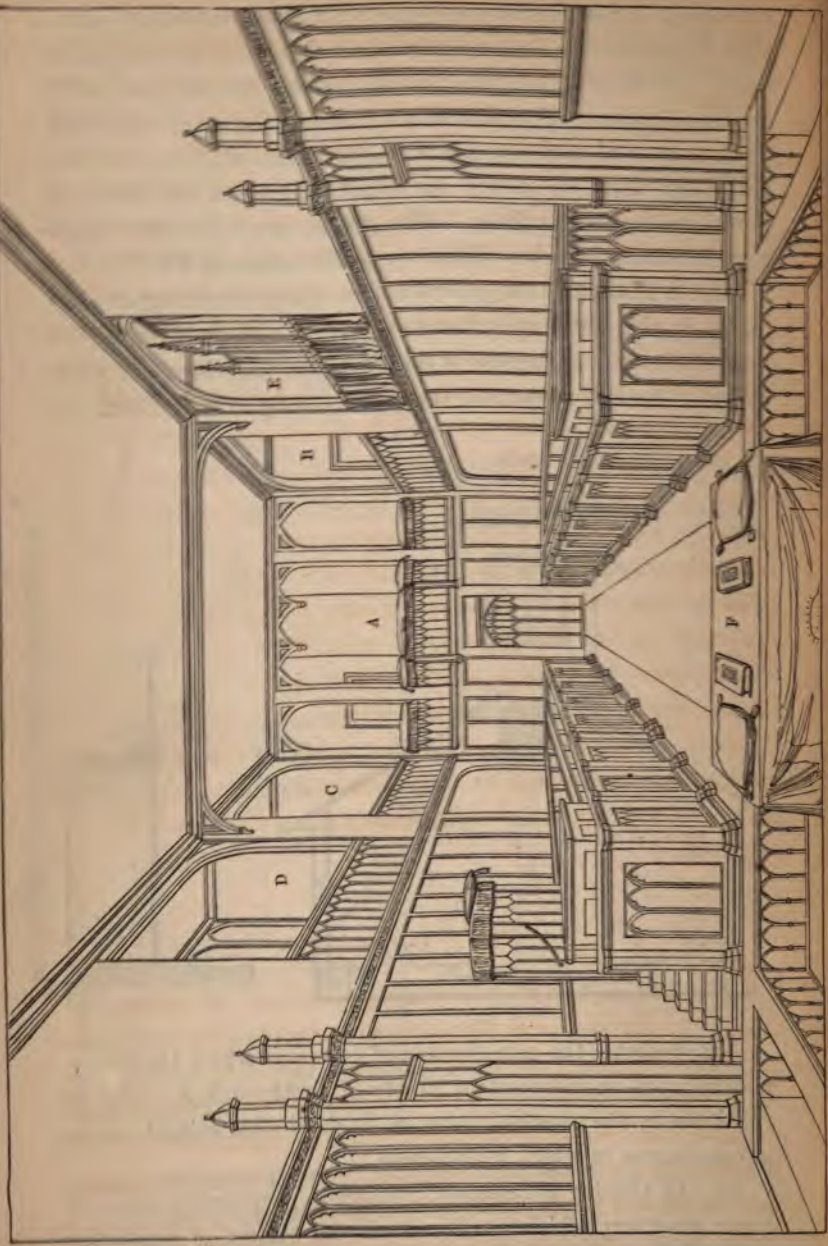


Fig. 9.

Fig. 9 shews the construction of pulpits in which the clergyman receives an independent supply of air through A, which he regulates by the attached valve, as he finds most suitable to the circumstances in which he is placed.

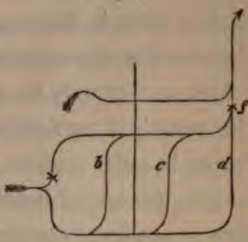
86. In altering old chapels, numerous peculiarities often require attention, which modify much the system of ventilation

Fig. 10.



that would otherwise be adopted. Fig. 10 gives a view of the Chapel-Royal, St James's; A is the royal pew or closet; B seats for peeresses; C seats for the lords in waiting; D additional seats; E the organ-loft; F the communion-table. In ventilating this place, the ingress of air had to be made through the floor, which was formerly a church-yard, and air and water-tight channels extended in cement. The effect of a large window had to be counteracted, which caused an incessant descent of cold air upon the communion-table in winter; chimneys from three fire-places had to be united with the ventilating shaft, otherwise they would have smoked continuously, and fresh air had to be conveyed to the royal closet, so as to repel the vitiated air which formerly rendered it the most oppressive seat in the chapel. Fig. 11 represents the system adopted under these circumstances; *b c d* indicate the circulation of the air through the body of the church; *f* the point where power was applied, which secured the movement of the air; the upper line shews the progress of the flue from the three chimneys. The mark on the ascending line, immediately after the feather of the lower arrow, points out the commencement of the supply for the royal closet.

Fig. 11.



Sect. III.—*Grave-Yards.*

87. Since modern chemistry has pointed out the precise nature of the circumstances that attend the decay of the body after it is placed in the grave, more just views have been entertained of the pernicious nature of those emanations that proceed from crowded grave-yards, particularly since the publications of Mr Walker, the Report of the Committee of the House of Commons, and the Report by Mr Chadwick on Interments.

88. Under certain circumstances where the body is not interred, it becomes dried naturally, even in temperate climates, as well as in

other regions, without embalming, after a limited portion shall have decayed. One of the most marked instances of this kind which I have seen, is exhibited in the body of the Duke de Croy, which is placed in the Church of St Nicolai, at Reval (in Finland). He fought with the Russians against the Swedes, about a hundred and forty years ago, and having died in debt to the extent of three millions of rubles, his body was seized and placed in a common coffin in the church mentioned. The debt not having been paid by his friends, as was anticipated, the coffin was opened, after a lapse of a hundred and eighteen years. To the surprise of all, it appeared merely to have become dry; even, at present, the character of the countenance is distinctly indicated; it is not much darker than is frequently observed in natives of this country; the skin has the appearance of leather. Instead of being concealed as formerly in an obscure situation, it now forms one of the principal curiosities in Reval. In other places, as when frozen in polar regions, or dried in the sands of Arabia, the body may be preserved indefinitely without being embalmed, but it is rare to observe examples such as this presents, in similar climates. In Austria, Sicily, and Italy, however, many examples are familiarly known.

89. In ordinary circumstances, the principal part of the body is slowly resolved into gases, and these tend ultimately to form carbonic acid, nitric acid, and water; the most offensive and dangerous products are those that are formed before the full oxygenation ensues. A long period has elapsed, since cemeteries were prohibited in many large cities on the Continent, and, agreeing with those who advocate similar views in this country, it is only necessary for me to refer, in connection with this question, to the elaborate report by Mr Chadwick, lately published under the authority of the Home Office, for much important and interesting information on this question. Not only is the air injured, but water also becomes seriously affected, in many places, by the emanations from grave-yards, and tends to produce disease. Many years ago, my attention was particularly directed to this subject by observing a film on the surface of some water,

which I afterwards found had been taken from one of the pump wells in this city, and which consisted evidently of the products of putrefaction from the grave-yard. In a moral point of view, no one who has ever seen and examined the state of many of the cemeteries that have been made on the Continent within the last fifty years, and the visits that are so frequently and periodically paid by the living to the graves of the dead, must be anxious that the inhabitants of this country should see so sacred an object placed universally, where it is practicable, on an equally desirable footing.

90. In the great majority of cases, in a climate such as this country presents, the whole area of a long used and crowded church-yard may be justly considered, in a practical point of view, as a manufactory of pestilential exhalations, perpetually in operation, and so abundantly supplied with the materials of production, that at no time probably is their discharge entirely arrested, however marked it may be at some periods compared with others, according to the state of the weather. And, since the laws of the diffusion of gases have been more thoroughly understood, and the practice in the majority of church-yards made known, no one who considers the facts connected with this subject, can hesitate to believe that even where the graves are considerably deeper than usual, this newly appreciated power of diffusion must operate incessantly with extreme effect in communicating deleterious products to the superincumbent atmosphere, so long as there is any thing to be decomposed. But severe as the effects may be, that are induced, in such cases, by their local action, and important as it may be to obviate them, still, when viewed in connection with the general series of changes that take place at the surface of the globe, they must evidently be considered as the natural result of those operations, without which, the materials composing the corporeal frame of man would not amalgamate with their kindred dust, and be made amenable to the action of a new cycle of changes.

91. It would be well worth the most serious consideration, whether means should not be taken to promote rather than to

arrest or retard the decomposition of the human frame, without outraging the sympathies of our common nature, or interfering in any way with those recollections and associations which it is equally natural and important to cultivate. The mere removal of the large gravestones that cover so many churchyards, the introduction of proper foot-paths, and the cultivation of flowers and shrubs, luxuriant in their vegetation, but not lofty or prone to prove any serious impediment to the free flow of air or the action of light, would be of incalculable value in numerous situations, absorbing the products of decomposition, and replacing, in general, by their purifying influence, a better atmosphere than could otherwise be sustained. Many other arrangements, applicable in special localities, will at once occur to those who adopt such views, which will give considerable relief in innumerable situations; and though the injurious influence arising from the practice of burying within as well as without the church, cannot be expected to be entirely removed except by legislative enactment, still an alteration in the structure of coffins, the use of a limited portion of lime, and, above all, luxuriant vegetation, might greatly reduce the evils of the present practice till further changes are enforced.

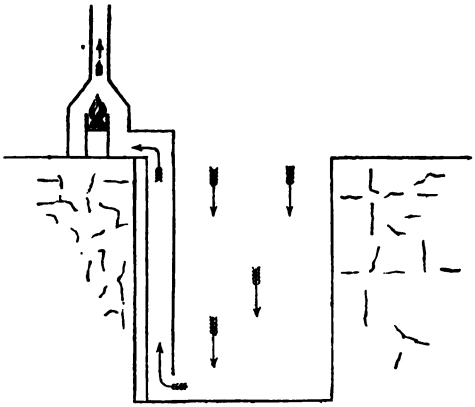
92. In some churchyards, I have noticed the ground to be absolutely saturated with carbonic acid gas, so that whenever a deep grave was dug, it was filled in a few hours afterwards with such an amount of this gas, that the workmen could not descend without danger. See Appendix, p. 432.

93. The amount of carbonic acid that collects within a given time in a deep grave-pit, intended to receive twenty or thirty bodies, is much influenced by the nature of the ground. In the case referred to in the Appendix, the porous texture of the earth allowed a comparatively free aerial communication below the surface of the ground throughout its whole extent. It was in reality loaded with carbonic acid, in the same manner as other places are loaded with water; it was only necessary to sink a pit, and a well of carbonic acid was formed, into which a constant stream of the same gas continued perpetually to filter

from the adjacent earth, according to the extent to which it was removed.

94. Fig. 12 shews a small ventilating apparatus, such as enables a grave-digger to continue at his work in the deep grave-pits without danger of suffocation. A small screw or fanner

Fig. 12.



may be occasionally found more convenient when the grave requires to be cleared out only in the morning, but is not so good when the workman is digging, unless it be sustained continuously in action.

SECT. IV.—*External Ventilation, Prevention of Noxious Exhalations from the Ground, and Emanations from Drains.*

95. CLEANSING, DRAINAGE, AND SEWERAGE.—Though the evils of defective ventilation in the interior of ordinary habitations generally far exceed in power and magnitude any effects from without, where a reasonable attention is given to external cleansing and drainage, still the low standard adopted in respect to these in numerous districts, and the almost total absence of cleansing and drainage in others, especially where the density of the population most imperiously demands it, give rise to an amount of disease, suffering, and death, which has justly at-

tracted the attention both of the government and the legislature. Until proper regulations on these points shall be introduced throughout the country, and adequate supplies of water be provided, no security for the removal of sources of impurity that largely affect the atmosphere can be given; and their extent in many places is so great, that, in the more extreme cases, some habitations may be compared more justly to the dens of the inferior animals than to the abodes of men. The universal attention now given to this question must be attended with the happiest results, and no one in this city can have witnessed the interesting experiment now in progress in Regent Street, where the zeal of Mr Cochrane, the president of the Society for Promoting the Cleansing of the Metropolis, has produced results that have equally surprised and delighted all that are familiar with them, who will not be anxious that he may succeed in shewing that he will be able to find additional and permanent employment for numbers in the more crowded streets, and that the advantages arising to health, and the saving in the destruction of goods, as well as other circumstances, will place this subject on that practical footing which will give a reasonable expectation of the system being continued and extended. Ingenious improvements, such as Mr Whitworth's machine, will also tend greatly to promote cleansing in populous cities, particularly in thoroughfares crowded with vehicles, where it is impracticable during the day time to resort to ordinary labour.

96. The importance of effective drainage and sewerage has been shown, of late years, in so many reports from all parts of the kingdom, that its influence on health, strength, and length of life, is gradually beginning to be more generally understood. The results of all inquiries abundantly demonstrate, that drainage and sewerage are essential elements of health in populous districts. Independently of actual loss of life, which so frequently occurs, impaired mental or bodily vigour, arising from the influence of defective drainage and sewerage, reduces daily, in thousands of cases, the capabilities of individuals to such an

extent, that it may be considered equivalent to a loss of income, by the deterioration or diminution it induces in the effective services which each can give to his own occupation. If we look to the humblest classes of society, how severe is the loss occasioned by fever, whether it shall attack the head of the family, and deprive them of the ordinary means of subsistence, or occupy the time and attention of the parents, when it may have affected their children. But no fact is more familiar to medical men than that many districts are never free from fever, in consequence of defective drainage. Calculated merely as a matter of profit and loss, every thing indicates that the expense required in establishing proper measures for such purposes, would be far below the loss consequent upon the inefficient arrangements at present in operation.

97. Before any extended improvements can be anticipated, a larger supply of water may be generally considered indispensable, and the introduction of the most improved form of sewers and drains, such as admit of a rapid flow of water, or the adoption of special means for washing the drains and sewers from time to time, by collecting and discharging suddenly a considerable body of water, so as to prevent periodical accumulations. The entire abolition of cesspools, even where they communicate with drains, will at once remove the most fertile sources of disease in numerous districts, if proper drainage and sewerage be substituted; and where this cannot be done, still, by removing them from under houses, constructing them with materials absolutely air and water tight,* and providing a proper exit for discharge when they are full, much may be done to alleviate the evils they otherwise produce, particularly by affecting the ground in the vicinity, and providing a constant source of emanations equally offensive and injurious to life. In short, ventilation can only supply bad air where drainage and sewerage is defective, though it may alleviate the intensity of the accumulated

* In some cases a coating of soft pitch is the most efficient and economical protection against leakage.

evils that would otherwise prey upon the system. The leading points bearing on ventilation that require attention in connection with cleansing, drainage, and sewerage, are stated in the Appendix, p. 434 and 436.

98. Extreme neglect may be perceived, in general, in the amount of security provided against vitiated air from sewers, and the means for this purpose are so imperfect, and a proper system of inspection so rarely enforced, that the atmosphere from drains often forms a marked source of supply, in many public and private buildings. From numerous instances which I have seen, I have quoted a few in the Appendix, p. 436-7, which will give some idea of the importance of a more minute attention being generally directed to drainage and sewerage in individual habitations or public buildings, independent of the introduction of general measures for promoting these objects.

99. But it would be tedious to multiply the endless variety of illustrations which might be added to those in the Appendix, without referring to humble habitations where the evil abounds in a still more glaring form. It will be evident, however, that in all classes of habitations or public buildings, besides those where the offence is gross, and manifest to the naked eye, the progress of the air from the open mouths of drains should be carefully studied, and controlled as local circumstances may indicate.

100. In some places, vegetation may be resorted to as a means of drainage, where other measures cannot be adopted, and in particular strata, wells may be sunk which will act as pits of absorption, from which an effective drainage is carried on, through porous textures, whose nature and extent removes all apprehension of any danger from the saturation of the ground, however dangerous this may be in other localities. The addition of lime or other chemicals, where the soil has been largely impregnated with deleterious products, is often advantageous, in the same manner as lime-washing and fumigations are in individual habitations.

101. Figs. 13 and 14 represent a plan and section illustrative

Fig. 13.

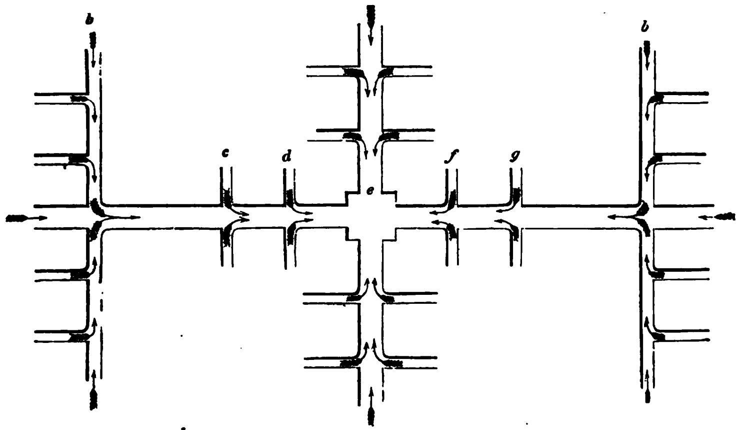
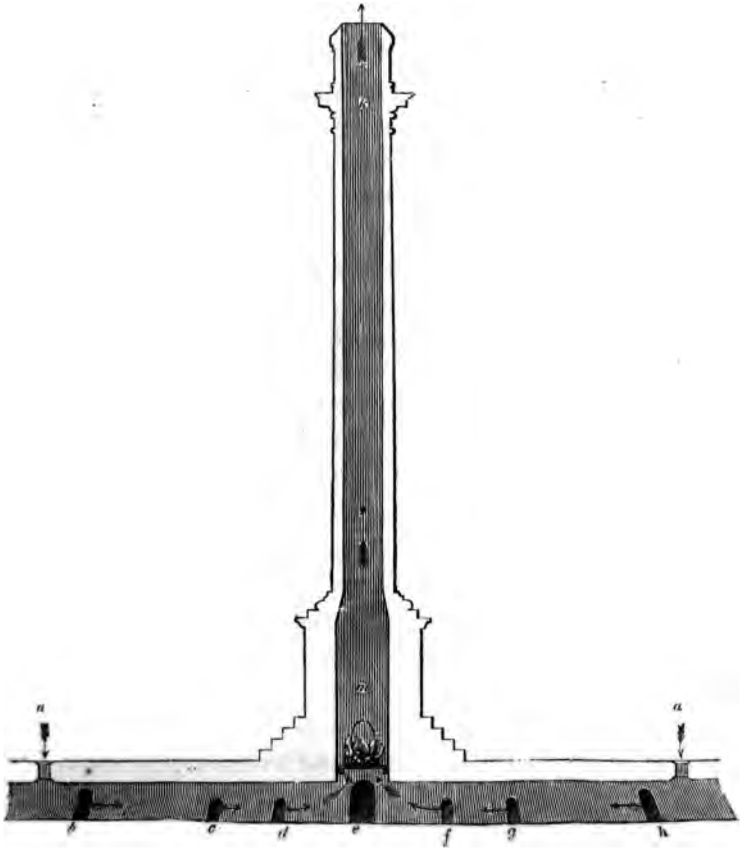


Fig. 14.



of the mode which I have adopted for many years, where it was necessary to ventilate drains. Arrangements of this kind were more particularly introduced in my class-room, in 1833, and subsequently at the House of Commons, at Hospitals, at Courts of Law, in private houses, and in numerous other places. In the section, *a* represents air in the streets, descending by the gully-holes, passing ultimately, by various channels indicated, viz. *b c d e f g*, &c., to a common centre, and from it to the shaft or chimney, by which it is to be discharged. A small fire sustained in the shaft, not only enables the shaft to have a very wide and commanding range, and, also, to expose offensive products to such a temperature as to alter completely their character, even where they may not be entirely consumed.

Sect. V.—*Noxious Gases, Vapours, and Smoke from Manufactories.*

102. In some manufactories, from which the most offensive products are discharged to the destruction of the health, and comfort of those in the vicinity, it should not be forgotten that the state of the atmosphere within may be good and wholesome, while the products evolved from the chimney, whether visible or invisible, may destroy the purity of the air without. Hence, then, any fair report founded on the inspection of the workmen in the place where the evil is produced, must necessarily lead to the opinion, that no cause of offence does exist, while the very same parties, had they examined the air without, would have seen a very different case. The advocate in defence urges as strongly the accuracy of his case, producing evidence from within, as the advocate for the prosecution is satisfied with the intolerable nature of the evil he has to attack, taking his evidence from without; while the fact that the workmen are actually protected from injury by the nature of the processes, and the position where the noxious products are formed often escapes observation.

103. The magnitude of the evil produced by manufactories must not, in all cases, be measured by the amount of visible

vapours produced. Many cases occur where the contending parties may at first be satisfied with the visible diminution in the amount of products evolved; but they often assume a still more dangerous, because invisible, condition. Until a power of inspection is given, and the disposition and consumption of materials in manufactories, prone to produce nuisance, be satisfactorily shewn, the mere reduction in the amount of visible vapours should be held as no security that no evil is produced, and reasonable and well-certified complaints should entitle an examination to be made within the premises, such as may elicit the facts of the case, otherwise changes may be effected which evade the arm of the law without relieving the just complaints of the sufferer.

104. Offensive emanations from manufactories consisting principally of impurities, capable of being consumed or altered by fire, so as to lose their most objectionable qualities, or of being retained by the action of common water, or of water charged with lime, or other ingredients, and brought into contact with them in such a manner as each peculiar case may render necessary, there is no impossibility in controlling their effects. But unless the means adopted be economical, it is in vain to expect a practical result; in many cases, the processes that have been hitherto proposed would more than consume all the profits of the manufacturers; a complex question, accordingly, often occurs which involves the continuance or abandonment of a manufactory, upon which the occupation of numbers may depend. The unwillingness in general to force matters to extremities, leads many nuisances to be tolerated that would not otherwise be submitted to. Great progress, however, has been made, latterly, in the study of the means of decomposing or condensing noxious emanations. The following diagrams explain some of the principal methods that have been generally introduced:—

Fig. 15 shews a section illustrative of the principle on which emanations from boilers are drawn through fires, where they are decomposed by the heat to which they are subjected; the

ash-pit *b*, is inclosed by a door, so that the fire is supplied solely with air from *a*. When the principal fire is not in use, a smaller

Fig. 15.

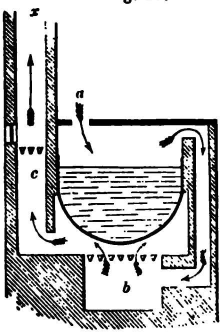
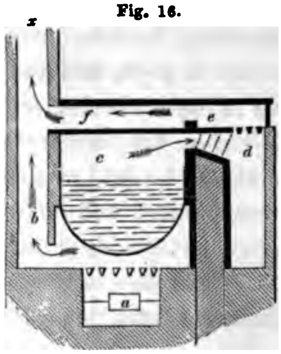


Fig. 16.



fire is kindled at *c*, so as to insure complete decomposition before the products escape at *x*.

Fig. 16 shews a better arrangement for the same purpose. The ordinary fire is managed in the usual manner, no more air being admitted at *a* than may be absolutely necessary, so that the chimney *h* shall be left with abundance of power to command another fire-place *d*; through this, all products from *c* are led, and pass ultimately to *x* by *f*. The wire-gauze between *c* and *d* prevents the passage of any cinder from the fire-place *d* to the boiler, and in cases where any considerable amount of inflammable gas is evolved, the fire *d* must be removed to a greater distance.

Fig. 17 shews a plan of the furnace-bars at *d*. Fresh fuel is never laid upon them, but upon the plate *e*, and transferred to *d* by a valve, as those previously there are consumed. In this manner, the fire is always maintained at a high temperature at *d*, and fresh air being admitted at *o o*, it is not extinguished under any circumstances, if made sufficiently large at first, and properly attended, though it may burn dully from time to time in the centre. Fig. 18 is a section of the same fire-place; *m* points out the position of the passage for air, or other substances to be decomposed, from the boiler to the decomposing furnace.

105. Fig. 19 illustrates Mr Hedley's patent arrangement

for condensing acid gases, smoke, fumes from lead and copper, smelting-works, and other manufactories, the flue from the fur-

Fig. 17.

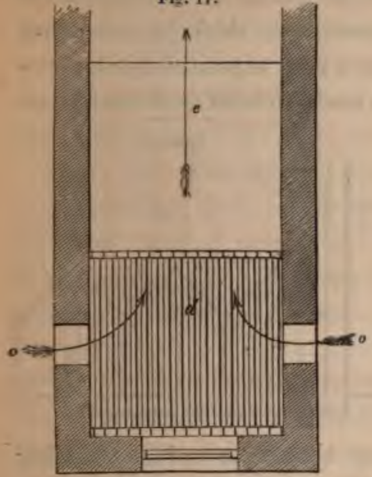
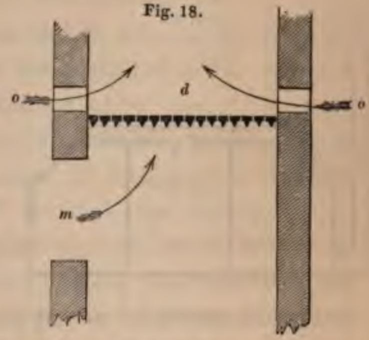


Fig. 18.



nace passing as the arrow indicates, and the draught being sustained by descending showers, supplied by a pipe fed by a steam-engine, or in any other way that local circumstances may

Fig. 19.

render more suitable. The valve on the left regulates the rapidity of the escape of the uncondensed gases that are subjected to the action of the water in the descending shafts. The products collected below may, in some cases, be so valuable as to repay the cost of the apparatus.

106. Figs. 20 and 21 shew the mode of ventilating air-tight stores, apartments, or manufactories, where the nature of the fumes evolved are such that none are permitted to escape until subjected to some purifying processes in the shaft, by connecting arrangements with it, such as have been explained by the preceding figures. The air may be made to take an ascending or

Fig. 20.

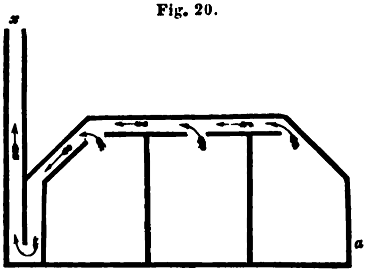
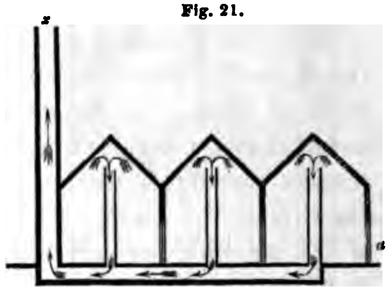


Fig. 21.



descending movement at any place between *a* and *x*, according to the disposition of the vitiated air-channels.

107. The SMOKE from manufactories so frequently presents a source of extreme annoyance, in consequence of the quantity of soot evolved, that this subject has deservedly attracted much attention, independent of those cases where deleterious gases are discharged. Let any one watch the amount of soot at times produced by a single chimney, let him examine in detail the discomfort and the expense thereby entailed on thousands, and the destruction of furniture and clothing which become saturated with it, while there is also reason to believe, that, in some cases, it enters the lungs to a certain extent, and clogs or obstructs the minute tubes that lead to the air-cells,—and he will be abundantly satisfied that no manufacturers ought to be permitted to allow smoke to escape to the extent that is always observed, where no special arrangements are made to prevent it. Farther, in much the greater number of cases, the smoke that appears is a loss of fuel to the manufacturer; and hence, as in numerous other cases of nuisance, his own interest is connected intimately with the question. The subject is necessarily very extensive in connection with the extremely varied use of fuel in

the operations of art. The report lately published on the smoke nuisance, gives ample details of the numerous ingenious arrangements proposed for the prevention of smoke. The extracts in the Appendix, explanatory of the nature of smoke, are taken from a paper which I drew up lately for the Committee of the House of Commons, in which a general view is taken of the principal materials to which the term *smoke* has been applied.

108. The preceding observations, in this section and in the Appendix, having explained the nature of smoke, and the mode of treating deleterious and offensive emanations from manufactories, using this term in its widest acceptation, it only remains to refer to the combustion of carbonaceous smokes. Equality in the distribution of the fuel, and the opposition of hot air with sufficient oxygen, are the great desiderata in all arrangements for consuming smoke. A regulated and divided entrance of air, the introduction of prepared fuel by machinery, the rotation of circular grates, the rotation of bars, the infusion of air by a blast upon the top of the fuel, the action of steam, and numerous other plans, have been tried with very various success, according to the nature of the fuel in use, the care with which the apparatus has been fitted, and the attention paid in managing it. Common bituminous coal instantly gives out gas when sharply heated, and this gas is consumed or produces smoke as it is supplied with air. The result of all experience tends to shew, that it is generally highly economical and advantageous to the manufacturer to consume smoke, when proper boilers are used. But when too small boilers are employed in proportion to the power required, the necessary amount of steam is not always to be obtained except by excessive firing, when a large quantity of smoke is almost invariably produced. No cases demonstrate, in a more convincing manner, the extreme importance of the general introduction of elementary science as a branch of education, than those connected with the use and disposition of fuel, where a little more knowledge on the part of those who manage the fires would be attended with the most beneficial results, and enable them to

extend indefinitely improvements in the use of fuel, and in the construction of furnaces.

Fig. 22.

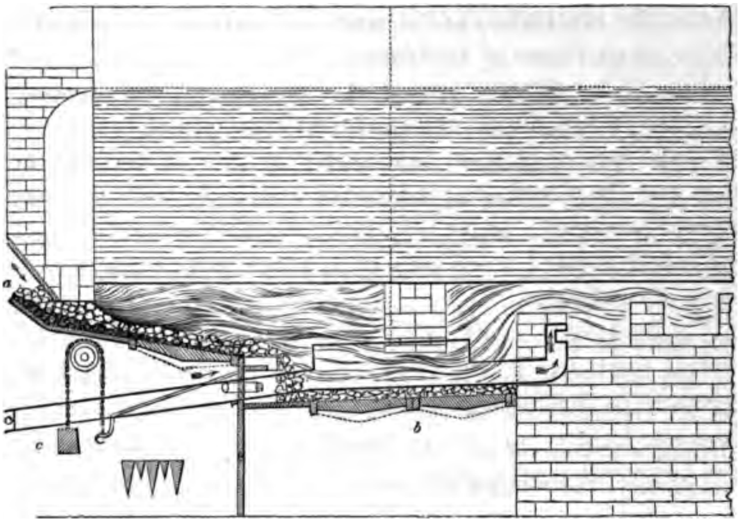
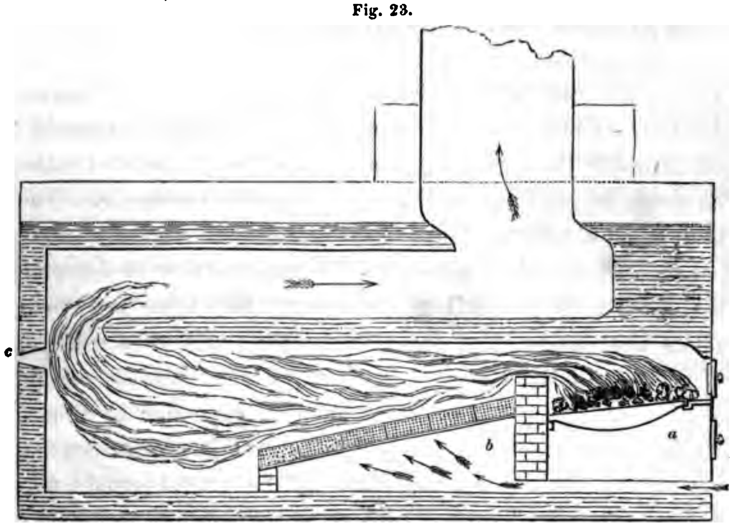


Fig. 23.



Figs. 22 and 23 shew two of the forms of furnace that have been used for the consumption of smoke. Fig. 22 is a section of one of Mr Chanter's furnaces, in which the principal peculia-

rities are the power of preventing the access of air from below to the first part of the furnace, by shutting the valve connected with the weight *c*, and of introducing air in the centre of the bars, so as to consume the products evolved in the first part, which receive only a small portion of air from *a*.

Fig. 23 is a section of one of Mr Williams' argand furnaces, in which part of the air is admitted with extreme diffusion beyond the furnace-bars, the first supply for the fuel being given at *a*, and the second, from *b*, being directed exclusively upon the gaseous products. In Mr Williams' book on his argand furnace, the reader will find much interesting information on the phenomena of combustion.

The limits of this work do not allow me to enter more minutely on this question; the report of the Committee of the House of Commons on Smoke contains very full information on the various processes hitherto proposed; a report published at Leeds may also be consulted with advantage.

SECT. VI.—*Carbonometer*.

109. In estimating the condition of atmospheric air, so far as it is required for ordinary purposes, it would be a great point gained were some familiar test introduced, which could be applied with facility in indicating its purity, in the same manner as the thermometer is employed for indicating temperature. For this purpose, I have employed, more particularly during the last eight years, various modes of estimating the amount of carbonic acid in the atmosphere, such as are usually resorted to in the chemical laboratory, but have found none so convenient for ordinary purposes, without the laboratory, when individuals, unacquainted with chemical details, were to apply and interpret the results, as those where a solution of lime-water or baryta were applied, so as to point out generally the amount of carbonic acid which might be present in the air under examination.

110. Carbonic acid being the principal impurity communicated to air by the processes of respiration and combustion, as

well as in numerous other operations, it will be obvious that where it predominates, other impurities may also be in general expected. Hence, then, though no general analysis of air can ever supersede the necessity of local inquiries under peculiar circumstances, still, a more general attention to the amount of carbonic acid in ordinary apartments, would be as important as the use of the thermometer and the hygrometer; its influence insidiously gains upon the person, and is not likely to be otherwise forced upon the attention; the state of the atmosphere in schools is intolerable, in many cases, to those who may enter from without, while those in the school may be insensible to the deterioration which has gradually and silently taken place since they may have entered.

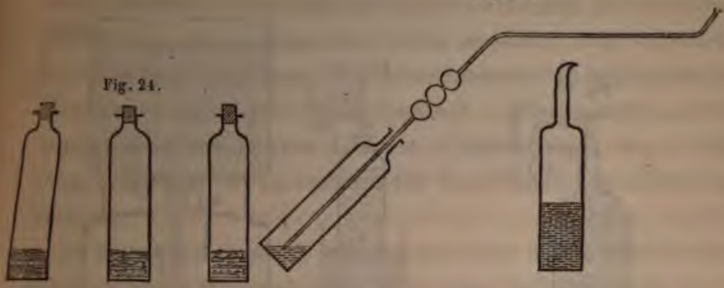
111. Though carbonic acid, accordingly, may be the more predominating and important impurity which it may in general be necessary to check, it must not be forgotten that much information is still required as to the details of its action, and the extent to which it is modified by the influence of carbonic oxide or other ingredients, with which it is often mixed. These operate with so much force in some cases, that death has ensued at times in the lower animals, where the amount of carbonic acid was only 1-5th to 1-3d of what it was in other cases before life was extinct. M. Le Blanc attributes the excessive influence, occasionally attributed to carbonic acid, to the presence of carbonic oxide, and has adduced some very remarkable and important illustrations in proof of this opinion.

112. A little lime-water, or barytic water, introduced into an ounce phial containing the air of the apartment under examination, immediately indicates the presence or absence of carbonic acid, by the precipitation or non-precipitation of a compound of the earth, and the carbonic acid which the air may contain. The accompanying phials (Fig. 24) represent the varied appearances shewn, after the action of the test, according to the quantity of carbonic acid present. The manner in which air is occasionally drawn through a minute quantity of barytic water, by means of a syringe attached to a tube, is

shewn by Fig. 25. In coal-mines, I have occasionally employed a minute quantity of barytic water poured on a fragment of coal,

Fig. 25.

Fig. 24.



and in schools, a small portion placed in any glass is sufficient. But, in other cases, the annexed forms of an instrument I have termed the carbonometer has been used, which enabled the experiment to be made with definite quantities of air. The operator soon acquires sufficient experience to judge of the general nature of the atmosphere, from the amount of deposit or turbidity in the clear solution employed. The worst air I have hitherto met with was in a printing-office lighted by gas; the lime-water became coated with a crust as soon as it was poured out. In preserving specimens, the best mode consists in sealing hermetically the bottles containing the air, by fusing the neck of the phial, as shewn in Fig. 25.

113. As atmospheric air always contains a minute quantity of carbonic acid, a long exposure, even to common air, would ultimately produce a white deposit, similar to what is more rapidly formed in impure air. Hence, the velocity of movement ought always to be taken into consideration where no definite amount of air is used, as, under other circumstances, no dependence could be placed upon the result. The more precise method of proceeding, and one well adapted for schools, churches, and crowded assemblies, consists in employing a carbonometer, if it be desired to have at all times the means of ascertaining the condition of the air.

114. The CARBONOMETER consists essentially of any vessel,

as represented in the annexed Figs. 26, 27, 28, which, when filled with water, determines a current of air to pass through the

Fig. 26.

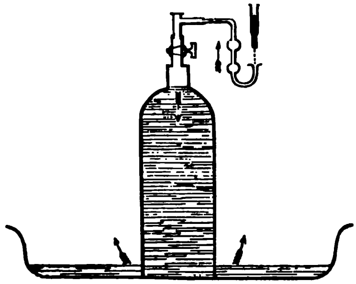


Fig.. 27.

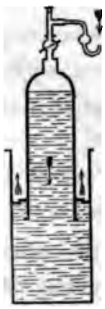
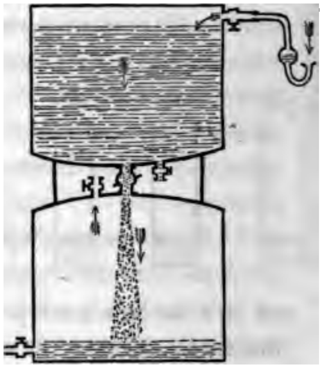


Fig. 28.



small glass attached to the upper part, the water being permitted to descend by its own gravity, on opening the intermediate stop-cock. And as the stop-cock is opened only so as to admit the water to escape drop by drop, the carbonic acid acts freely on the chemical agent in solution in the small bulb, as the air passes through it, and fills the void induced by the descent of the water. The bottomless bottle, Fig. 26, is filled with water by a syringe fixed temporarily at the top; 27 is filled with water by merely dipping it in the water, and replacing it on the shelf. To obtain a new observation with Fig. 28, it requires merely to be inverted, arranging it again as the figure explains. By contrasting the effect produced by the descent of fifty cubic inches of water in the open air with that seen when the air is loaded with carbonic acid, a careful observer will soon be able to draw satisfactory conclusions from his experiments. When the precipitate is not reserved for use, dilute muriatic acid dissolves it rapidly; after removing it altogether, the bulb is ready for a fresh observation.

115. Lime-water is sufficient for ordinary purposes. It is prepared by agitating a tablespoonful of newly slaked lime in a bottle of water from time to time, decanting the liquid for use

as it is required, when the undissolved lime in excess may have subsided. Barytic water is preferable, being much more prompt in its indications, from the greater strength of the solution which can be procured. Insoluble carbonates are formed in both cases. The facility of preparing lime-water in almost any situation, recommends it for general use, when comparative indications to be tested by the eye alone are required. Where many experiments have been performed within a limited time, the air has occasionally been drawn through the test-water by an exhausting syringe.

116. An ounce phial, full of lime-water, when emptied in a great measure, but retaining a little, about half a drachm, to act on the air which enters, is occasionally used. This is not so desirable a mode of proceeding, as part of the carbonic acid, as it enters, is lost in the lime-water which escapes. An experienced eye will judge of the purity of air, by merely agitating lime or barytic water in a wine-glass.

117. In all these experiments, the operator must take care that the effect of the breath from his own nostrils, or that of others, be carefully guarded against, otherwise the results cannot be relied on. Let him blow a little air from the lungs into a drachm of lime or barytic water, and he will soon see the rapid formation of an insoluble carbonate, and the necessity of this precaution.

CHAPTER III.

ARCHITECTURE AND VENTILATION.

118. It has been admitted, of late, that warming and ventilating arrangements ought to be defined more particularly than has commonly been the case, before any building is commenced, and incorporated with the original structure from its foundation. This is, unquestionably, a great step in advance; but we would venture to urge that it is short of the necessity of the case, and generally below the standard which economy of execution and the maintenance of health demand. This subject can never, indeed, be placed on the most desirable footing till the architect shall always design in unison with the principles of ventilation, and make them a primary, instead of a mere secondary, consideration, in his structural arrangements. When this principle is not adopted, the means of economic ventilation may too often be considered as superseded, before any attention has been bestowed upon them. Due and adequate ventilation is too intimately connected with the whole suite of architectural arrangements to admit of being introduced advantageously, in all structures, whatever may be their form and disposition. The mobility of air is such, that it can be made to move in any direction that may be required, but the ecónomy or facility of executing such movements form very different questions.

119. Till the last century was far advanced, the constitution of atmospheric air, and consequently its precise relation to the human frame, were unknown. Since these, however, have been pointed out, and, at a period when the progress of art and science is daily unfolding and applying new resources and new materials

to all the varied demands of architecture, it would be singular, indeed, were increased importance and consideration not given to those facts and principles which tell more directly to health, strength, and length of life, than any others that can be brought to bear on the construction of the habitations of men. And, after all, though the invisible air is too apt to be forgotten amidst the more obvious attractions of architectural art, still, in a practical point of view, the visible structure is only the shell or body of that interior atmosphere without which existence could not be supported, while it is also the medium of intellectual communication, and the channel through which heat, light, and electricity convey their influence upon the human frame. It is no exaggeration to say, that along with those means of defence and seclusion which they naturally present, the great and primary object of architecture is to afford the power of sustaining an artificial atmosphere, such as the constitution under each variety of local circumstances may require. It is, in reality, to every building what the breath of life is to the human frame—the vivifying principle, without which they would be tenantless and uninhabitable.

120. It is sometimes argued that ventilation is expensive, and that the cost is such as to preclude the general introduction of extended arrangements, similar to those that have been adopted in some buildings. Such reasoning has no force, unless viewed in connection with the special circumstances of each individual case. Systems of ventilation are often compared by parties who never take the trouble to enquire as to the amount of air which each may be capable of supplying, and which is essential to meet the peculiar position to which it is to be applied. A system may be good in principle, but totally deficient in the amount of supply. It is not expensive to ventilate any place, if this primary question be kept out of view; but large as the quantities of air may have been which have been supplied in different public buildings, I am not aware of one where the supply on those occasions when ventilation is most loudly demanded, in which it has not been below rather than above the

amount which would have been acceptable. Ventilation ought, accordingly, to be considered in a twofold aspect, in the same manner as food, clothing, or any thing else, where one proportion is essential for existence under any circumstances, while any thing beyond this should be viewed in the light of a luxury adapted to the circumstances of each individual case, and in connection with the amount of value which the individual to benefit by it may be inclined to place upon it. In this point of view, the following may perhaps be considered a proper exposition of the facts of the case, in respect to the expense of ventilation :—

121. I. Were ventilation made a primary consideration in construction, and designs formed in unison with those laws that admit of its most economical application, it would be much less expensive than when appended to buildings previously designed or already built, and advantage might be taken of many alterations which would necessarily diminish the expense incurred specially for it. For instance, numerous apartments are daily constructed of a much greater altitude than is required where systematic ventilation is introduced, for the purpose of giving an ample supply of air. In such apartments, though air is longer in becoming vitiated, it is also longer before it is purified when once the vitiation has taken place. But, with systematic ventilation, a pure atmosphere can always be sustained within the zone of respiration, though the walls of the apartment be not elevated higher than the heads of those who may occupy them. The economy effected by reductions of altitude in individual apartments, though only amounting to one or two feet on each floor, would, in most instances, amply repay any expense incurred in improving the ventilation.

122. II. Were central shafts preferred for ordinary purposes, whether for individual houses, public buildings, or for commanding streets, squares, or districts, the permanent economy and improved health which would necessarily attend their

introduction, ought not to be forgotten in estimating their actual cost.

123. III. In individual apartments, an ingress and an egress for air, controlling valves, and such diffusion as the numbers likely to occupy each apartment might render necessary, forming the great essentials of ventilation, a great expense would not be necessary, if the requisite means were introduced in the original structure.

124. IV. In old buildings, the introduction of systematic ventilation may be expensive or not, according to the facilities they present, the amount of ventilation required, and the condition of the atmosphere accessible. In some places, old churchyards have had to be opened, and air-tight tunnels carried through them. At the Old Bailey, a tunnel had to be made which cut through the Old London Wall, and traversed old drains and sewers, from all of which it had to be defended in cement; a peculiar site was also selected for the ingress of air, that it might have the purest air the district could afford, where chimneys from eating-houses, in which, at least, a thousand people dine daily, drains not prevented from evolving gaseous emanations, soot, chimneys from workshops, from which most offensive fumes are discharged upon the Court windows, and the air of the whole district very often affected by the neighbouring markets,—all tended to modify the details of the plans adopted.

125. V. Again, the constant efflux of vitiated air would prove a great antidote to dry-rot, by removing that moisture, carbonic acid, and insensible exhalations of animal matter, which form the great food of dry-rot in non-ventilated apartments. To prevent dry rot, we must either reduce or increase the temperature at which the material is sustained so as to render vegetation impossible, without the aerial or other pabulum by which it is supported, or impregnate it with materials which are of such a nature as to resist or oppose its progress. Effective ventilation not only removes the pabulum that otherwise accumulates, particularly in crowded buildings, and also tends, by its oxygenating

influence, to burn or pare off many products that frequently tend to aggregate and present a nest or basis for vegetation. But in all cases where there is either peculiar exposure—a difficulty in obtaining constant and free access to the timbers,—or a desire to give the highest protection, the materials should be subjected to those agents whose antiseptic powers tend to oppose all incipient vegetation. Among these, the muriate of zinc introduced by Sir W. Burnett, which I have used on different occasions, and which, from the specimens I have seen, is the most powerful of those materials that do not affect the texture or other qualities of the wood, and Mr Payne's process, by which different materials are made to re-act upon each other through the substance of the wood, a process by which the wood is altered in its texture, claim more especial attention. Many oily antiseptics, though offensive from their odour, are also effectual in preventing dry-rot. But, as yet, I have not seen any specimens of wood or canvass that have resisted such trying circumstances as those that were protected by the muriate of zinc.

126. VI. The expense of ventilation tells principally in cold weather, where abundance of fuel is necessary to maintain a supply of warm air in proportion to the amount consumed; but as valves are provided in all systematic ventilation, by which every individual can increase or reduce the supply to any extent that he may consider desirable, this is no just objection to the introduction of extended measures for ventilation, which, if well arranged in ordinary habitations, will work effectively in summer at little or no cost, when a large amount of ventilation is principally required. Further, in winter, the comparatively small amount of moisture in solution in the air renders less air necessary for ventilation than in summer.

127. VII. The increased brilliancy of illumination generally introduced by lamps, or otherwise, since the application of gaslight to artificial lighting, demands a greater amount of ventilation than was formerly required, even where oil-lamps and candles may alone be used. Health cannot, in this respect, be placed on

the same footing as formerly, unless the lighting be reduced, or the ventilation be extended.

128. VIII. If heat be produced so as to warm the hall and passages of ordinary habitations economically by an Arnott stove, or a mild hot-water apparatus, and these be made the great reservoirs and source of fresh and warm air, the ventilation will be greatly simplified. The want of an acknowledged ingress of fresh air of sufficient magnitude is as great an evil as a defective egress, though in large works recently published the egress alone is mentioned as being necessary.* But when an egress alone is provided, it must act practically, both as an ingress and egress, and be accompanied by offensive descending currents of cold and impure air from above, if the usual position for the discharge be selected, or be supplied irregularly from casual sources, otherwise no ventilation whatever can ensue.

129. IX. Lastly, the management of the most ordinary ventilation is rarely understood in houses having only a very few apartments; and, perhaps, more expense, discomfort, and annoyance, frequently arises from this cause than from any other, particularly where both those that give and those that receive orders do not distinctly understand whether they have or have not the means of accomplishing what they desire. General education can alone obviate this evil.

130. Were the ventilation of whole streets, as well as public buildings, placed on a systematic footing, thousands of towers, spires, pillars, and minarets, &c. &c., would gradually replace

* The paragraph referred to is in the following words, which constitute the entire article on ventilation in a work on architecture numbering upwards of a thousand pages :—

"The continual supply of fresh air to an apartment is a subject which latterly has been considered so necessary, though much neglected, as the moderns seem to think, by their ancestors, that a volume would not hold the schemes that have been latterly proposed for that purpose. Generally, it is enough for the architect to provide means for letting off the hot air of an apartment or building by apertures at the upper part of the rooms, &c., to which the hot air will ascend without afflicting with the currents of fresh air that are to be introduced those that inhabit them."

the tens and hundreds of thousands of common chimneys that are at present seen on almost every dwelling, and afford not only more effective means of supporting health, but also innumerable opportunities of introducing useful structures, which, at the same time, might be rendered highly ornamental. The frontispiece represents, on the left, St George's Hall, and the new Assize Courts, designed by Mr Elmes, and now in course of erection under his direction at Liverpool, in the large vacant area opposite the railway station at Liverpool. The hall alone will accommodate four thousand people; and in the new disposition of the ground, it will be obvious that few places would present a more fit opportunity for the ventilation of a whole district under the operation of some central power, as indicated by the large shaft beyond the building in the centre, or for constructing a central range, when a smaller shaft, confined to it alone, might be made both useful and ornamental.

131. Systematic ventilation would permit the use of gas in all public buildings or private dwelling-houses, as thus no leakage would discharge any gas except into the ventilating tubes, and no products of combustion could mingle with the air of the apartment, were they treated in the manner explained in the paragraphs on exclusive lighting. At present, however, the intolerable oppression produced by excessive gas lighting arises at times not only from the escape of unconsumed gas, but also from the return of the products of combustion to the zone of respiration.

132. Again, few circumstances would contribute more to the general use of smokeless fuel, and, consequently, the general prevention, or, at all events, the extreme reduction of smoke, even in ordinary habitations, were ventilation greatly extended. Three causes, in particular, concur to this effect, viz., the anxiety to exclude the large amount of soot that at present penetrates all varieties of dwellings in large and densely populated cities;— the enlarged consumption of gas that may be anticipated when exclusive gas-burners are used for ordinary illumination, and the consequent production of a corresponding large quantity of smoke-

less fuel, while the more extended use of gas as a heating power, both for domestic use and in the arts, must contribute to the same effect;—and, lastly, the more abundant production of anthracite, and the greater familiarity with the proper method of using it, even for open fires. This subject will be again adverted to in explaining the means of producing and communicating heat.

133. Such a course would not only prove a remedy against smoke, but increase the tendency to combine and beautify the discharging channels or shafts for smoke-flues, as they would not then be subject to those sooty emanations which would otherwise tend rapidly to disfigure them.

134. It would equally remove one of the most frequent causes of fires, and entirely abolish any necessity for sweeping chimneys either by machinery or by climbing-boys, and, therefore, prove the most effectual barrier to all evasion of the humane and salutary law that was introduced on this question. I may mention here, as I have elsewhere stated, that for ten years I have had numerous flues in operation, in none of which has raw coal ever been employed, except for the purpose of illustration, and that they have never required the slightest sweeping.

135. In many old buildings which have been altered under my directions, the large amount of shavings and broken wood has amply explained the rapidity with which many fires spread at first, when a light or flaming spark has fallen amongst them, and the facilities which have too often been afforded for the development of fire by slow combustion bursting ultimately into flame, where oil, or any other similar material, has found its way amongst such materials. A practice is also very common, in many places, of sweeping rooms after sprinkling them with saw-dust, and of throwing in quantities of saw-dust into roofs prone to exhibit signs of leakage upon the ceiling, so as to absorb the water.

136. All such practices cannot be too severely reprobated, particularly after the various facts that have been discovered as to slow combustion, and that even charcoal, in particular conditions, ignites with facility at a temperature of 280°.

137. It would be well, indeed, were all builders compelled to

report whether attention had been paid to the clearing away of all useless timber and shavings, particularly as this latter often enters into decay, and gives an ample pabulum for the production of dry-rot. In one of the last buildings to which my attention was called in this country, the fresh air entered over an enormous quantity of such materials, black with soot, and in a complete state of decomposition. In one place, nearly twenty carts of saw-dust were removed. At the Old Bailey, in introducing the ventilating arrangements adopted there, about ten carts of decayed timber and loose useless wood were removed, all of which previously contributed to influence the state of the atmosphere. Were a coroner for fires appointed to investigate the causes of every serious calamity from this source, society would soon become more alive to many of the causes of fire which might be avoided.

138. It would add greatly to the perfection of the architectural structure, were all arrangements for artificial light laid down in public buildings before commencing them. And in streets, or large suites of buildings, when intended for public purposes, it would be well to consider whether, in a certain number of houses, all could not be supplied generally with heat, steam, hot water, and ventilation, on the same principle as they are now supplied with cold water and with gas, without in any way compromising that individuality or seclusion which every private dwelling at present commands, though the water, the gas, and the drainage, of which it reaps the advantage at present, is common to it and many others at the same time.

139. The four first figures in the Appendix, viz., Figs. 312, 313, 314, 315, point out some arrangements for consideration in entering upon the question of general ventilation, to be effected by a single shaft, and illustrate the mode of arranging hot water apparatus, when not aggregated so as to produce great heat in one locality, but rather to give a mild and equal warmth to the whole building.

140. In general architectural arrangements, the elevation of the ventilating discharge, or aperture, to the highest accessible

altitude, and its protection by a cowl, by louvres, or any ornamental structure, such as may be employed alone, or for concealing them, adds greatly to the facility of ventilation.

141. Figs. 29 and 30 point out the usual form of the cowl and the louvres, the cowl being always surmounted with a vane,

Fig. 29.

Fig. 30.

and finished as the building on which it is placed may require. A few more figures are given in the Appendix. The largest cowl I have used is at the Old Bailey. It is fifteen feet in diameter, runs upon rollers, besides being supported on a central mast, and weighs two tons. The barb of the arrow which forms the vane is made of cast-iron, and weighs one hundred and seventy pounds. This cowl was constructed by Mr W. Cubitt, of Gray's Inn Road, and has worked with great steadiness and equality. In most other places where cowls have been introduced, they have been concealed by louvres or other arrangements.

142. In the queries in the Appendix, which are illustrated by some diagrammatic lines, a number of circumstances are noticed, which should be kept in view in considering the nature and practice of ventilation. The feathers of the arrows are intended, in all the diagrams, to indicate the ingress of air, and the barbs the discharge, while the body shews its course, or the number of different channels into which the primary stream of air is often split, and the number of individual streams which are subsequently gathered into a single discharge.

143. No reference is made in these queries to windows, as it is presumed that, however desirable it may be to have the power

of opening a window in an ordinary apartment, it is better to provide independent channels for the ingress of fresh air.

144. If a window be opened to a very trifling extent above and below, it may give in many cases all the ventilation absolutely required; nevertheless, the local action of air from doors and windows cannot be too carefully guarded against. John Urquhart, whose whole time, for several years past, had been directed with great zeal and care in carrying into execution the various rules given for the management of the equalizing chambers for the ventilation at the Houses of Parliament, and who escaped the effects of severe exposure in the various hot, cold, and mixed air-channels into which it was necessary for him to pass and repass continually, whenever the Houses were sitting, went to Gravesend for a few days, and having slept with the window open, a current of cold air which played upon him as he slept, led to an attack of inflammation, and he died in three days. He was an extremely stout man, in the prime of life, and moderate in all his habits. Cold air may be offensive to the feet, but it is much more dangerous as it plays upon the lungs and organs of respiration, and various cases, such as the above, indicate the importance of the means of giving diffusion to the air that comes in contact with the person.

145. Cold glass also produces a descending current of air, which is very offensive to numerous constitutions. Double windows, as will be explained hereafter, remove this defect.

146. When moisture appears on a window, it always indicates that the air which deposited the moisture was saturated with it, supposing its temperature to be similar to that of the glass on which it falls.

PART II.

NATURE OF VENTILATION, AND THE MEANS BY WHICH IT IS EFFECTED.

CHAPTER I.

NATURE OF VENTILATION.

147. VENTILATION consists essentially in the supply of fresh air to any apartment, and the removal of that which has been vitiated. Without the use of air-pumps, or other artificial means, it is impossible to discharge air, however small the quantity (the temperature of the air being constant), without a corresponding ingress from the external atmosphere: a proper entrance for the fresh air, and a proper exit for the vitiated air, are accordingly the first desiderata. Without these, no arrangements, however satisfactory in other respects, can be considered as being placed on a systematic footing. An ingress and egress might certainly, under peculiar circumstances, be effected alternately by one and the same aperture, and satisfy all the essential wants of nature, as in the case of ordinary respiration, where the mouth and nostrils serve as a passage for air, both in inspiration and expiration; but, unless its action were sustained by a mechanism, as powerful in proportion to the movement of the air required, and as regular and effective in its operation, it would be vain to expect that it would meet the demands of ordinary ventilation. An endless variety of cases might be pointed out, where ventilating arrange-

ments have been rendered useless by the neglect of proper measures for the ingress of air.

148. In numerous instances it will be seen, on minute investigation, that an apparent discharge is provided for the escape of vitiated air, where none in reality exists. Thus, in churches, hospitals, and other buildings to which my attention has been directed, it has not unfrequently happened that large apertures in the ceilings led to air-tight roofs; and even where there might be apertures in the actual roof, still they were too often of little or no use, in consequence of their inadequate area, or from the vitiated air escaping through the ceiling becoming subsequently condensed in the roof as its temperature fell, and returning in endless currents, so as continually to contaminate the air in the apartment from which it had escaped.

149. Few points are of more practical importance than the proper management of vitiated air, as it escapes from the ceiling of any apartment in which it may be produced; and, in particular, it ought rarely to be permitted to extend and diffuse itself under a cold roof, but be conveyed in a distinct channel or ventiduct, till it shall escape altogether into the external atmosphere. To allow vitiated air to escape generally under the roof of any building in cold weather, is to commit an error precisely parallel to that which would be so objectionable in the management of drains, were water from them permitted to flood the pavement of any building, instead of being conveyed directly by special communications to the sewer outside. In summer weather, there would undoubtedly during the day be less objections to such a course, as the heat of the sun might then be expected to determine generally an ascending current; but, at other times, the current would descend, as on all occasions when the cooling power of the roof exceeded the effect of such warmth as might be produced within.

150. In the greater proportion of cases, air finds access to apartments in very variable proportions, by doors and windows, and consequently, the providing of a discharge for the vitiated air is the more important object, and the greater the altitude to which

warm and vitiated air can be conveyed before it mingles with fresh cold air, the greater is its ascending force, and the certainty with which it is discharged.

151. Irregular and uncertain channels for the ingress of air, difficult of control, and ever varying with the condition of the external atmosphere, are the true source of offensive draughts and currents, which, to many, are still more obnoxious than vitiated air. The latter may undermine the constitution by a slow action, but draughts and currents produce cough, colds, rheumatisms, pleurisies, and other inflammations, which not unfrequently prove quickly fatal, and are therefore justly dreaded, in consequence of the greater violence and rapidity of their action, particularly as their first effects at the same time render them more palpable than those developed by a vitiated atmosphere.

152. A moment's reflection will satisfy the mere student as to the truth of the position, that, unless a new portion of air be admitted into any ordinary apartment, the portion which is already there will not be expelled. It is the force of the air entering that causes the vitiated air to be expelled. It is necessarily impossible to have ventilation without a movement of air. At all times a tendency to movements in the air, or the production of a draught or current, may be observed, proportional to any inequalities of temperature that may arise from natural or other causes, or the action of any mechanical force. But though it is in vain to expect ventilation without movement of air, still, when this movement is duly regulated, according to the temperature of the air and the wants of the system, it is either altogether imperceptible, or at least inoffensive, and therefore rarely becomes the subject of remark; but if it be excessive, then it forcibly arrests the attention, and increasing complaints consequently ensue.

153. It would be well for those who suffer from draughts and currents, and who constantly declaim against any movement of air, to consider,—That their bodies have been so formed that the air never stagnates around them during life: That a slow, but

equal and continuous, current ever moves around the living frame: That it is not the mere movement of air which is the cause of offence, but the movement of air in proportions, or of a character uncongenial to the condition of the system at the moment: That even the most delicate ladies, who express their horror of draughts and currents, practically increase, from time to time, the movement of air that impinges upon them in warm atmospheres, with their fans, producing an agreeable and refreshing atmosphere with air which is oppressive and offensive, when not assisted to this inordinate movement: That the greater the degree to which the movements of air may have been reduced, the more does the system become sensitive to any renewal of its wonted action; and that the best means of obviating those effects which are so much dreaded, consist in so regulating the movements of air, that it shall never be reduced excessively, and thus the system can never be heated up to that point when draughts and cold currents become dangerous as well as offensive.

154. Finally, on this point, it cannot be too strongly inculcated, that the perfection of ventilation consists in the free supply of air so completely attuned to, and in harmony with, the frame upon which it acts, that its operation is not perceived. It should steal so gently upon it, that the attention is not roused into any consciousness of its presence. It may then be termed an acclimated atmosphere. Rude and local currents, whether cold or hot, always indicate imperfections, which should be banished or controlled wherever permission can be obtained. These remarks are made on the supposition that the system is in a neutral condition at the moment, and not excited by any recent exercise, or by excessive diet; nor, on the other hand, depressed by too great abstinence, or any other cause. In such cases, a colder atmosphere or a brisker motion becomes more agreeable to the over-excited constitution, and the reverse to that which is depressed.

155. It will be obvious, accordingly, that unless an appropriate channel be provided for the ingress of air, its movements cannot be controlled, and that it is as important to take proper steps

for the ingress of fresh air, as for the egress of that which is vitiated, these two operations being inseparably associated with and dependent on each other.

156. The next question that ought to engage attention, is the course which the air ought to take in proceeding through any apartment. Here it may be observed, that, in this country, air, vitiated by respiration, tends invariably upwards, after it has overcome the momentary impulse communicated to it by the force of expiration. The products of combustion follow a similar course, and also those evolved from the surface of the body. Hence, then, it may be stated as a general rule, that vitiated air collects above in any apartment more than below, and that an ascending movement should be given accordingly to the air which enters, so that when once it has come in contact with the system it may be propelled onwards, and never return again to the zone of respiration (the space from which the air is received when inspired by the nostrils), but be continually succeeded by fresh accessions of pure air.

157. The ascending movement is also the natural system. Were vitiated air to descend, in a very short time the surface of many districts would become so largely contaminated with it, that disease and death would speedily ensue on every side. It may be assumed, then, that a system which is not only in unison with the laws of nature, but also that which almost universal experience dictates, may be safely followed as a guide in leading us to give a decided preference to ascending movements in all ordinary cases where this may be practicable.

158. In cases of forced ventilation, where the ingress and egress of air is subject to the action of a power that may be regulated at pleasure, it may be expedient, under peculiar circumstances, and where special difficulties present themselves, to resort to a descending movement, leading the air from the ceiling to the floor, instead of from the floor to the ceiling. Such movements are necessarily more expensive than the ordinary ascending movement; they are applicable only where the products of combustion, from lamps, candles, or gas, are removed by

exclusive processes* from the descending atmosphere; they should be resorted to only where peculiar difficulties occur which cannot be overcome by other means. At one period, when it was affirmed that peculiar difficulties presented themselves in regulating the atmosphere of the House of Commons, I made several trials with the descending atmosphere, considering it, under these circumstances, the most desirable for that building; but subsequent investigations led me to ascertain that the objections made at that period were not tenable, when the arrangements were maintained in proper operation, and no descending atmosphere accordingly has ever been introduced during the debates. It may be stated, however, that as the first movement of the air from the nostrils proceeds in a downward direction, it would not be impossible to prevent the expired air from returning again upon the system by a downward movement, where very large quantities of air are freely introduced.

159. The more desirable ascending movement is not so imperative, generally speaking, in all cases where the supply of air is large and abundant; but unless this be strictly attended to, a descending movement is considered objectionable, not only from its greater expense, and from its returning vitiated products upon the system, but also from its tendency to produce disagreeable effects as it impinges upon the head, unless warmed to a point somewhat higher than would otherwise be necessary.

160. Again, in some cases, in lunatic asylums, in hospitals, and in numerous operations of art, a descending atmosphere is very desirable; while in museums, galleries of art and science, and all similar establishments, a mixed movement is preferable, by which dust is carried directly downwards from the floor, while the moisture of the breath, and products of combustion and respiration, are discharged above.

161. A lateral movement from side to side is not desirable, as in all crowded assemblies, where such a system is introduced, or even where the movement is from the side alone to the ceiling,

* See Lighting.

those nearest the side where the air first enters are subjected to the full influence of the current required for all, while others, at a distance, only receive an inferior quality of air, in consequence of its previous action on those over whom it may have passed in its progress towards them.

162. A mixed current, lateral at first, and ascending afterwards, is perhaps that which is most generally desirable and economically attainable in ordinary apartments, not crowded with many individuals.

163. It is a very common error to suppose, that, as carbonic acid is a very heavy gas, and one invariably produced by the process of respiration, and by the combustion of all the more common inflammables, the air vitiated by respiration and combustion tends to descend to the floor of any apartment in which it may be evolved; or that the carbonic acid always tends to separate from it and accumulate below. It is certainly true, that carbonic acid, when produced in a very concentrated form, does pass along the ground, and occupy, for a time, the lower portion, in the same manner as water, or any other fluid would do. This is abundantly manifest in the Valley of Death, in the Grotto del Cani, in brewers' vats, in many mines, in old wells and pits, in the vicinity of lime-kilns, and, in short, in all situations where it is evolved in quantity, and unmixed, or only associated with a limited proportion of air or other gases. But in all cases where carbonic acid has once mingled with a considerable proportion of air, as in the process of respiration, and in the combustion of an ordinary lamp or candle, it does not again separate from the gases with which it may have been blended, in consequence of its specific gravity, nor is it removed except by the operation of porous solids or powders,* or of chemicals which attract it and combine permanently with it, or decompose it and evolve oxygen, retaining the carbon.

164. Numerous facts prove the truth of this statement, and the appearance of carbonic acid gas in the highest regions of the

* See Absorption of Gases.

atmosphere which man has visited, affords ample proof of the law that has been explained in the paragraphs on the diffusion of gases, to which the reader is particularly referred, who may not previously have examined this point. It is not enough, however, to state that the carbonic acid evolved during respiration does not separate from the gases with which it is mingled; the expired air, as a whole, is specifically lighter, under ordinary circumstances, than the surrounding atmosphere, in consequence of its temperature, and the moisture associated with it. And, therefore, for a variable period after it is discharged from the lungs, even supposing the carbonic acid not to diffuse itself still farther in the atmosphere, the vitiated air remains above. If then, the vitiated air be removed by an opening above, it will be carried away with the least chance of contaminating the remaining atmosphere; whereas, in apartments where the air is withdrawn at a low level, and the usual temperature maintained, the products of respiration must perpetually tend to return upon the body from which the air has been expired.

165. In considering the level at which air ought to be withdrawn, no reference is, at present, made to the course which it may ultimately assume, after it has been extracted from the apartment in which it has been expired, but merely to the fact of its ascending power, even when diluted, with a large amount of colder air; that point will be referred to in succeeding paragraphs.

166. Diffusive Ventilation.—Numerous experiments having satisfied me that an amount of diffusion, far beyond what had been previously introduced, was necessary in supplying the quantity of air which I had been led to propose, it occurred to me, that the most effective means of accomplishing such an object would be to introduce universal diffusion in the apartment to be ventilated. I was led more particularly to endeavour to attain this object, in consequence of having noticed, that, in very crowded assemblies, adults may frequently be seen crowded together in different places, at the rate of one upon every square foot. At the Bar of the House of Peers, I have had frequent opportunities

of observing numbers crowded together in this proportion, and I am satisfied that, on many occasions, a still more dense aggregation of individuals may be observed in other places. In some experiments at the General Prison at Perth, it was found, that the men engaged on the works stood in the same proportion upon similar areas, 79 standing, in one case, in a cell having an area of 81 feet, and 90 in another whose area was 92 feet. And, in some trials made at the National Schools at Westminster, it was found that two boys (aged from 4 to 14) stood, without difficulty, on 1 square foot. In all these cases, no particular effort was made to induce either those at the prison or at the school to occupy the smallest possible space,—they were merely requested to stand as close as they conveniently could.* This extent of crowding is not to be considered rare in public meetings. Wherever extreme numbers are congregated on a given space at important and interesting trials, in the passages of crowded churches, and on other occasions, I have repeatedly seen the numbers as dense as I have mentioned. In a concert-room at Stockholm, I have seen the numbers more dense than on almost any other occasion; and even in buildings used for very different purposes, as in the Great Central Reception Room, at the Tuileries (the

* One of the densest crowds which I have witnessed, occurred opposite the hustings, in the High Street at Edinburgh, some years ago, where those towards the centre having been unable to resist the pressure at the head of one of the steep closes (lanes) which proceed from it, the moment they gave way a number of people were forced mechanically down the close, and a constant pressure being maintained by numbers pressing downwards from the Castle, and upwards from a lower part of the High Street, this singular movement was sustained from that period till the meeting began to disperse. The opposing streams produced the central current, which presented the singular spectacle of a current, in which the individual molecules were the human beings composing the crowd, and these, in many cases, had no sooner attained the central position to which they were pressing forward, than they found themselves involved in a current which they could not resist, and ultimately extruded from the High Street. I have no hesitation in expressing an opinion, that, at a particular part of this current, less than a square foot was the average space which each occupied, and in many places, where the pressure is very severe, the crowd must be equally dense; but, except in the cases to which I have specifically referred, I have not had the opportunity of noticing precisely the actual numbers that can be crowded in a given space.

Hall of the Marshals), this magnificent apartment presents in many places as dense a crowd as can be formed without injury to the person.

167. Without referring to extreme cases such as these, it is evident that the larger the surface by which a given quantity of air is permitted to enter any apartment, the less will its impetus be upon the person; and, therefore, the greater the degree of diffusion, the less will it tend to impinge offensively, and produce the disagreeable effect of a draught or current. Further, air entering by one or a few apertures only, often dashes along unequally through an apartment to be ventilated, leaving the atmosphere comparatively stagnant in some places, but producing sharp currents in others. Where the diffusion is great, the individuals who receive the fresh air will, in a great measure, be supplied share and share alike, according to the perfection of the arrangements, and none will be so placed as to be forced to respire the air that may have previously been respired by others. Diffusive ventilation not only secures these important arrangements, but, at the same time, admits of this introduction of air at a lower temperature than would otherwise be practicable without inconvenience.

168. The extent to which diffusion ought to be carried in individual apartments, must depend in a great measure on the numbers that may be expected to occupy them, and the amount of comfort desirable. As a general principle, the diffusion cannot be too universal. In a room for an invalid subject to cold or afflicted with consumption, the walls and floor might, if necessary, be rendered entirely porous for the admission of air, and the ceiling arranged in a similar manner for its discharge.

169. In ordinary apartments, a great amount of diffusion may be secured by taking advantage of the skirting for this purpose, and in all churches, lecture-rooms, schools, theatres, &c. considerable opportunities are generally presented, particularly in the rising steps, where air can be led in with diffusion.

170. In large apartments, occupied by a few individuals only, if the air be admitted at a distance from them, sufficient diffusion

may be secured by the extent to which the air may be broken in its course before it reaches them.

171. Again, the colder any air used for ventilation, the more important is it to attend to the amount of diffusion. (See observations on temperature.)

172. An extreme variety of textures have been employed for promoting diffusion, according to the circumstances under which they have been required. Hair-cloth is extremely useful from its perfect elasticity, and from its not being absorbent nor retentive of moisture. Wire-gauze, perforated zinc, and numerous woollen cottons, hemp, and silk textures, have been employed where different materials were required; they may be dyed or painted in imitation of oak, or according to any other pattern, so as to be in unison with the apartment in which they are placed.

CHAPTER II.

OF THE MOVING POWER REQUIRED FOR VENTILATION.

173. The extreme variety of circumstances under which processes for ventilation are applied, necessarily indicate that very various modes may be resorted to for inducing the required movement in the air.

174. For all ordinary purposes, the NATURAL method of VENTILATION will be found most eligible—that is, a process by which movements are induced or sustained in the air in the same manner as wind is produced in the external atmosphere, these movements being increased, when necessary, by the action of heat, and by the exertion of a shaft or chimney, that the heat may acquire additional force.

175. It is much questioned by various individuals, whether a fanner, or some other mechanical power, is not more efficient and economical; but this question is a little more complicated than is generally represented, and the following observations are given with the view of illustrating the more prominent circumstances that bear upon it.

176. As air constitutes, in one respect, a balance infinitely more delicate than any that man can make, and as the most trifling increase or diminution in the density of any portion of air leads it to press more or less heavily than before on that which is immediately in contact with it, circumstances, almost too inappreciable at first to be considered worthy of notice, can nevertheless so alter its specific gravity, that it immediately begins to press more heavily than before on that which surrounds it, or to give way before the pressure to which it may still be subjected

if its density be diminished. But though many popular misapprehensions are still entertained on this subject, it is universally acknowledged by all who have experimentally examined it, that the specific gravity of air vitiated by respiration or combustion,—the two great processes that deteriorate air in ordinary buildings,—is, under ordinary circumstances, less than that of common air; it gives way accordingly, and is pressed upwards by the denser and purer air. Let us imagine, then, an apartment occupied (not inconveniently crowded) by a number of persons standing on a porous floor, and the roof taken off; at ordinary temperatures, the air vitiated there by the human frame requires no mechanical power to remove it. The superincumbent pressure is diminished by the expansion induced in the air as it is heated, but the external atmosphere is permitted to have free access, below as well as above, to the porous floor. Its power, therefore, preponderates, and an upward movement is the necessary consequence, which is accompanied by the introduction of fresh air, and the removal of that which is vitiated. Here, then, is a species of natural ventilation. All that is essential is merely this, that the natural movements induced by the heat of the body shall not be stopped by any barrier which may be opposed to them. An open roof and ceiling, however, is, in the greater number of climates, inadmissible. Protection is required from the weather, independent of other arrangements; the opening, accordingly, may be contracted. In proportion to the amount of contraction, the temperature of the air, and the numbers on a given space, it now becomes necessary to increase the velocity of the discharge from the apartment referred to. To effect this, if a shaft or chimney be extended from any opening in or near the ceiling, the column of warm air, which soon fills it, increases its power, and, unless an extreme number of individuals be crowded in the apartment, the shaft is sufficient for all ordinary purposes. It acts at all times when the density of the air within is less than the density of the air without, and when this is not the case, its power can still be developed by kindling a lamp or fire, or merely by increasing the temperature of the apartment for which

it is supplied, as any of these causes produces the necessary diminution of density or rarefaction within, on which its force depends.

177. If, however, it be proposed to use a mechanical power for the same purpose, machinery in the first place, more or less simple, must be prepared. Power must be applied to the machinery by manual labour, by water, by a steam-engine, by a weight wound up from time to time, or in some other way, and however small the power actually required at any particular moment may be, it is more liable to accident, and more skill is required to maintain it in action. A chimney, therefore, from its extreme simplicity, and from the comparatively trifling attendance which it requires, is always preferable in numerous situations, while it involves no severe and long-continued manual labour, such as is apt to be neglected. Further, when properly finished at the top, the wind acts as a power, and, without any fire, often determines the ascent of air.

178. A precise knowledge of the manner in which heat acts in determining a movement in the air is so important, and explains so many phenomena of art and nature, that too much attention cannot be bestowed upon this subject till it is thoroughly understood. The following illustrations will facilitate the study of these movements.

179. Whenever a heated object is placed, as a candle, the air in contact with it (Fig. 31) immediately expands; bulk for bulk accordingly, air near it, but not yet expanded, is pressed under the expanded portion, and a current is thus established towards the source of heat, which is sustained so long as any inequality of temperature continues.

Fig. 31.

180. In the same manner, the air around the human frame is always warmed and expanded as it comes in contact with the body, and, in this condition, an atmosphere at a mean temperature, and not agitated by any wind, is usually elevated about five degrees in its temperature, as it rises and escapes above the head.

181. If the candle be introduced into a tube (Fig. 32),

the current of air which is thus established is more rapid in its ascent, unless the tube be extremely wide. The warm air, not being so accessible to the cold external air, a greater difference of temperature is established, which is accompanied by a corresponding difference of specific gravity and of velocity in the currents.

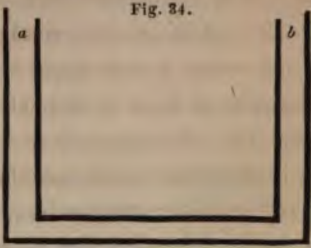
Fig. 32.

182. If the tube be very narrow, the expanded air within it is cooled still less quickly by the surrounding atmosphere; it attains a higher intensity of temperature; there is a greater amount of expansion, and a greater rapidity of movement in the tube. (Fig. 33.)

Fig. 33.

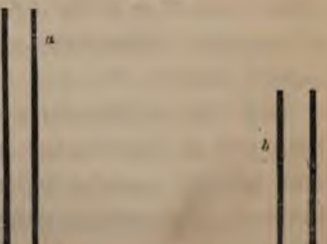
183. If two glass-tubes of equal size be connected together by a common base, the air in one limb may be said to counterbalance that in the other, each pressing against the other with the same amount of force, while both, at their open extremities, are subject to the pressure of the external atmosphere. The extreme delicacy of the balance, however, is such, that the slightest impulse that may tend to disturb the equilibrium, whether chemical or mechanical, must immediately establish a current in one direction or another through the tube, and cause the air to move from a to b, or in the opposite direction.

Fig. 34.



184. An inequality of height, as in Fig. 35, is often quite sufficient to determine a current, where none otherwise would take place, when there is a gentle movement in the external atmosphere, the one limb being more affected than the other.

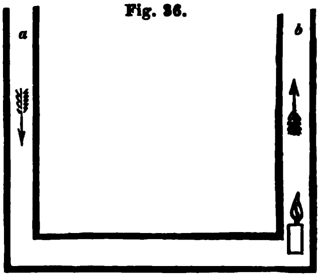
Fig. 35.



185. If a candle be kindled in one limb of the tube (Fig. 36), the cold air descends by the other, and is warmed as it ascends

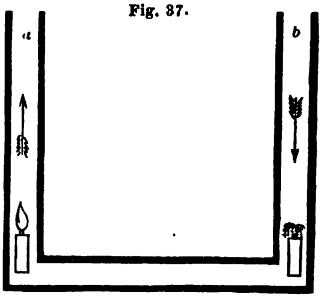
in the first, so that a continual current is maintained. In this manner it will be observed, that a descending current at a can now be as effectually maintained as an ascending current at b, and such is the manner in which descending currents are usually induced, where heat alone is employed for this purpose.

Fig. 36.



186. But if, while a current is in full motion from a to b, another candle be introduced into a, its tendency is to arrest the current, by inducing the same diminution of specific gravity in a that had formerly taken place in b. The circulation may then be entirely stopped; or the candle in b may be overpowered by the larger candle a, the smoke and flame being forced down b, and onwards to b, as is indicated by Fig. 37. It is scarcely necessary to remark, that the longer the heat may have been communicated to one limb of the glass, the more steadily can the current be maintained in that direction.

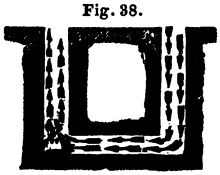
Fig. 37.



187. Similar movements are induced by fires kindled in mines, large apartments, chimneys, or under other circumstances, the *expanded warm air being always pressed upwards by any colder and denser air, and the movement being more or less rapid, according to the difference of temperature and amount of expansion between the air that is heated and the cold air in contact with it.*

188. Fig. 38 illustrates the manner in which the air circulates when heated in any shaft connected with another, as in a coal-mine; the air in both communicating freely with the atmosphere.

Fig. 38.



189. Fig. 39 shews the circulation so

long as any inequality of temperature is maintained in a confined atmosphere.

Fig. 39.

Fig. 40.

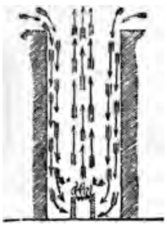


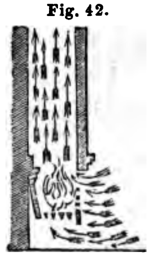
Fig. 41.

190. Fig. 40. If air be heated in any apartment or chimney freely exposed to the external atmosphere, a central ascending current is established by the heavier cold air, which descends on every side. Such currents often counteract each other in narrow shafts to such an extent, by the production of local eddies, that the movement of the air is impeded, and the fire below extinguished, from a defective supply of fresh air.

191. Fig. 41. If a fire be kindled in a chimney open above and below, the air flows in with great rapidity.

192. Fig. 42. In a common fire-place, much air passes above the fire as well as through the fuel to the chimney, and reduces the velocity of the current, moderating also the rapidity of the consumption of the fuel.

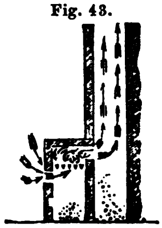
Fig. 42.



193. Fig. 43. In a furnace where a high temperature is required, no air being admitted to the chimney except what passes through the fuel, the heat is more intense, and the combustion more rapid, than in a common fire.

194. Fig. 44. If air be not supplied by the doors or windows of any apartment sufficient for the combustion of the fuel kindled in the chimney, a descending current is frequently observed in one part of the chimney, and an ascending current in another; the room, consequently, is filled with smoke.

Fig. 43.



195. Fig. 45. Air is sometimes introduced into apartments by one chimney, and carried away by another: and if the air

Fig. 44

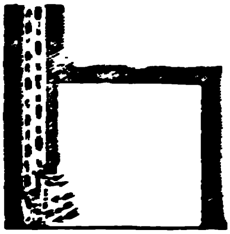
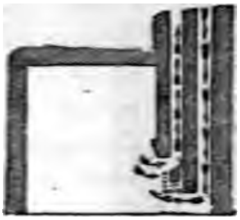


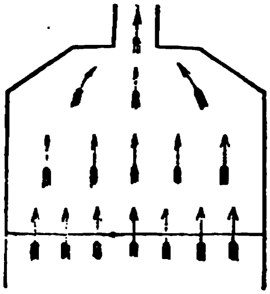
Fig. 45.



supplied be led in below or near the fire-place, the apartment is not subjected to those severe draughts that are often so offensive in ordinary apartments, where the air is not introduced with diffusion.

196. Fig. 46. Warm air introduced into any apartment is soon expelled, if freely subjected to the pressure of the external air from below the floor, and also allowed a sufficiently large escape at the ceiling. In such a position, the air may be considered as in a wide expanded chimney.

Fig. 46.



197. Fig. 47. The air, as it descends by a second chimney, is sometimes heated, by causing it

Fig. 47.

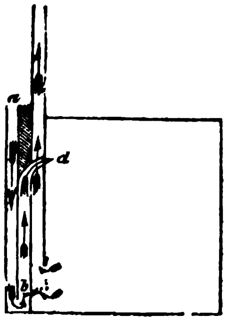
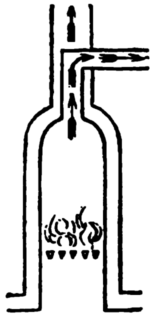


Fig. 48.



to come in contact with the iron frame-work of the grate before

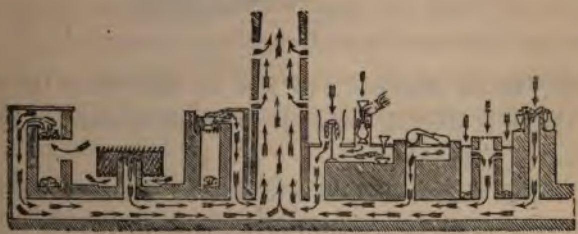
it enters the apartment which it is to heat. The figure represents the currents, according to the arrangements adopted by Mr Adams of Falkirk.

198. Fig. 48 points out the progress of the air in a common cockle, part escaping by the chimney, while the pure air is conveyed where warm air is required.

199. Figs. 49 and 50 present a view of the principal fur-

Fig. 49.

Fig. 50.



nace and ventilating arrangements connected with a chimney in the centre of my Class-room, at Edinburgh; part of them only can be worked at once, all connexion with the others being then cut off by means of valves. The arrows indicate the progress of the air from the different openings to the central shaft.

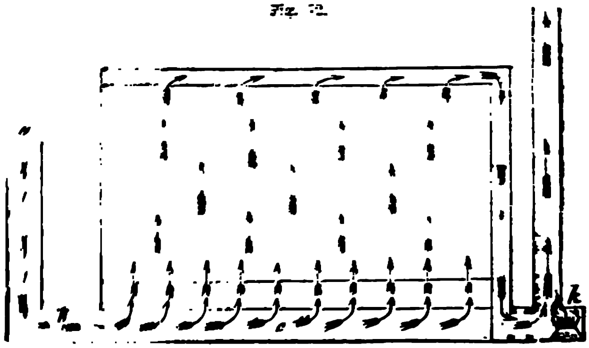
200. Fig. 51 is an enlarged view of one of the ventilating arrangements, shewn in the preceding figures, pointing out the manner in which noxious or offensive vapours are carried away; the fumes evolved, and the other phenomena observed, in con-

...ing different movements or processes, are seen through large ... cylindrical glass vessel. In this figure, a portion of ... combustion, a lurid flame

appearing, which descends two feet or more from the cup in which the oil is kindled, before it finally disappears in the flue that leads it to the shaft.

201. *Fig.* 72 is a section of one of the first ventilating

Fig. 72.



... rangements adopted, similar to those made in the House of

Commons. It is not so complete, however, and the position of the fire-place in the air-shaft renders it less powerful.

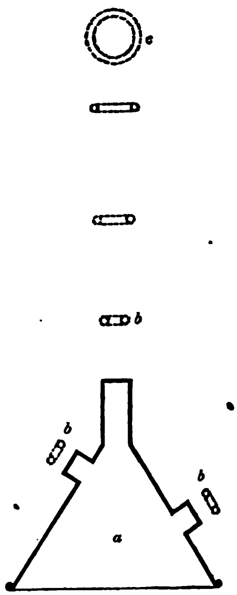
202. Again, if we look to the air as it escapes from any chimney, it will be seen that it tends to form numerous wreaths or rings, in consequence of the central portion being moved upwards at a greater velocity than that which is external, the motion at the circumference being retarded by the friction of the chimney through which it rises, as well as by the external descending current formed by the cold air outside, which complete the movement necessary to the production of wreaths or rings, whose constitution is exceedingly singular and interesting. (See Smoke).

203. On the small scale, the movements induced in air by a variety of temperature, can be shewn very beautifully by heating the air in a large glass shade or jar, after introducing various portions of phosphorus, of different sizes and forms, and supporting them within this shade or jar, at a height of one or two inches. Farther, if the air in the jar be heated to various temperatures before the experiments are made, by placing a lighted spirit-lamp in it, from time to time, for one or more minutes, the rapidity of the motion of the current from the phosphorus is necessarily varied, and they can then be studied with much more facility.

204. When air is projected rapidly from a chimney, the ascent of the interior warm portion, and the descent of the outer and colder portion, as mentioned above, necessarily leads to the formation of numerous wreaths or rings; and in all cases, even where coal-smoke, steam, or any vapour, is projected rapidly from a round aperture, it tends to produce a similar movement. A tin cone of the form shewn in Fig. 53, and covered with parchment at its base, if filled with visible vapour, gives a beautiful succession of rings or wreaths, from apertures at the end and sides, every time it is struck like a drum. Thus, the rings from a smoking chimney-top, the rings of steam and of other vapours that are seen in numerous chemical experiments, the wreath that is formed

at the mouth of a cannon as it is fired, on which some grease has been placed previously, and the rings that may be formed by opening any aperture from which steam is suddenly discharged, all arise from the cause adverted to. And even in great explosions, as at the siege of Acre, when the magazine blew up, a similar wreath is reported to have been formed, and to have risen to a great altitude in the air.

Fig. 53.



205. In a very calm and still atmosphere, and where the smoke is produced very equally, instead of isolated wreaths, continuous ascending and descending laminæ of smoke may be seen, or figures approximating to those represented in Figs. 54, 55, and 56. The study of the movements of air, rendered visible in this manner by smoke, has thrown much light on many points con-

Fig. 54.

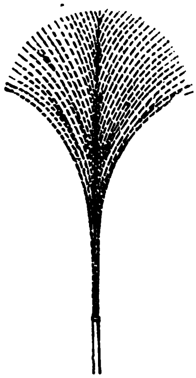
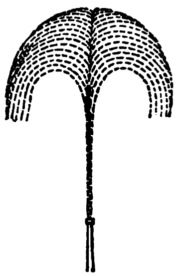


Fig. 55.

Fig. 56.



nected with the nature and practice of ventilation, and many

of the draughts and currents that are so frequently the subject of complaint, and connected with similar movements of air. They can often be easily traced when any trouble may be taken to examine into the cause, a little smoke formed near them indicating readily the mode in which they proceed.

206. When the WIND is strong, a very small aperture, if covered in a suitable manner, is sufficient to discharge a very considerable amount of air, as, when it sweeps past various chimney-tops or cowls, it induces a void in the chimney-top or cowl to a certain extent, if it strike upon it in a proper manner, and hence the air from within tends to join the general current of the external atmosphere.

207. In the same manner, if a STREAM OF AIR be discharged with great force in the interior of a chimney from a small tube, it propels rapidly the air in the chimney, and is followed, when proper dimensions are used, by a powerful stream of air, assisting greatly the ordinary movements of the chimney.

208. Though the power of the wind may often be very usefully employed as an adjunct to natural ventilation, in promoting the movement of air, its uncertain and ever-varying force, and at times its entire suspension during calm weather, prevent it from being resorted to, or, at least, depended upon, in numerous instances where the primary object is to secure at all times a determinate movement of air capable of being regulated with accuracy as circumstances may require. There are, however, a great number of cases where such precision is not necessary, and where, accordingly, a careful and judicious attention to the aperture by which vitiated air is discharged into the external atmosphere presents a power which it is important to take advantage of, as a movement in the air is much more common than an absolute calm, or at least, an inclination of the air so gentle as to have no practical effect as a motive power.

209. But the manner in which the wind strikes upon such discharging apertures is so dependent, not only upon its force, but also upon the peculiar position in which they may be placed, in respect to the natural heights, levels, or valleys with which they

may be surrounded, and the varied currents, deflections, and lo eddies that may be induced by adjoining buildings, high wall courts, lanes, and alleys, that the protected apertures which ar sufficient in some places, are totally useless in others. The more certainly the direct ingress of air is prevented on all sides when the wind is powerful, by numerous deflections, the less will be the danger of down-draught when sudden impetuous currents, constantly varying in their direction, beat upon these apertures.

210. By elevating the discharge, when this is practicable, above all high walls in the vicinity, greater immunity is obtained from the action of local eddies.

211. The influence of the wind upon any buildings is secured in the highest degree, when the aperture of ingress moves freely to the wind, so that it can enter these with the full force of the current, the aperture of egress being turned from the wind, so that, as it passes by, it shall act with the power of a pump in facilitating the discharge of air that may have entered by the first aperture mentioned.

212. A STREAM OF STEAM, introduced by a pipe from a boiler into any shaft or chimney, also operates in a similar manner by the mechanical impetus with which it impinges in the air, as well as by the elevation of temperature, and consequent rarefaction which it induces.

213. All these modes, and even the repulsion induced in the particles of the air by electric excitation, may be employed for determining movements in air, and some of them, as the action of steam in the chimney of the locomotive engine, are applied with great success; but when natural ventilation is not assisted by the action of a fire or other sources of heat, mechanical means are usually employed to promote it, where a more continuous and sustained equality of power is required than can be commanded by the very variable currents which the external atmosphere presents.

214. Among the mechanical means employed for the movement of air, the FAN has been used from time immemorial; and,

s simplicity, efficiency, and the facility with which it can ally applied, affords a powerful means of moving the air, ally when of large size, used by the attendants of the rich rm climates (Fig. 57), and wielded with the dexterity h they acquire by long practice.

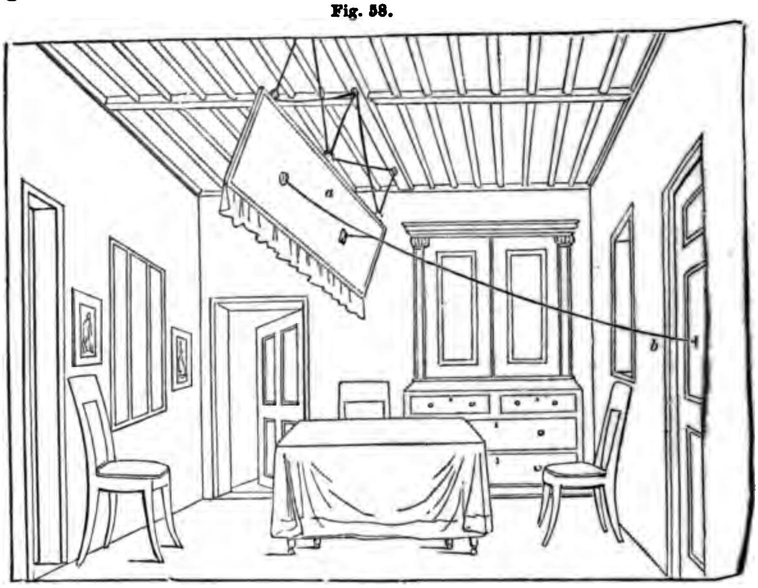
Fig. 57.

215. The PUNKAH, so common in India, may be considered a gigantic fan. It is placed in the centre of an apartment in general, above a bed, or table, or in any other position that may be more suitable, being suspended by cords and moved by a line held by one or more attendants, either in the apartment or outside, the line being conveyed, in the latter case, by an aperture through the wall (Fig. 58).

The punkah and the fan act essentially in the same manner, the velocity they communicate to the air enabling a larger quan-

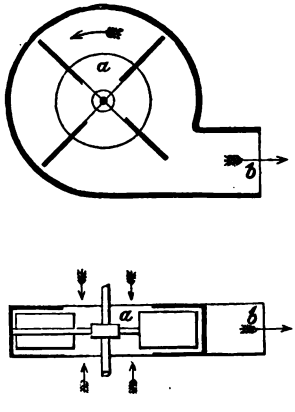
tity to come in contact with the face or the body generally in a given time.

Fig. 58.



216. Among the instruments that have been employed for the purposes of ventilation, none has been so very generally used as the FAN, FANNER, or BLOWER. This instrument, so well described by Desaguliers, has been made in a great variety of forms. Figs. 59, 60, represent its more common form. In the plan, two of the blades are shewn, the air entering at the centre (a) as the instrument is worked, and being discharged at the circumference b, as is seen more particularly in the section.

Figs. 59, 60.

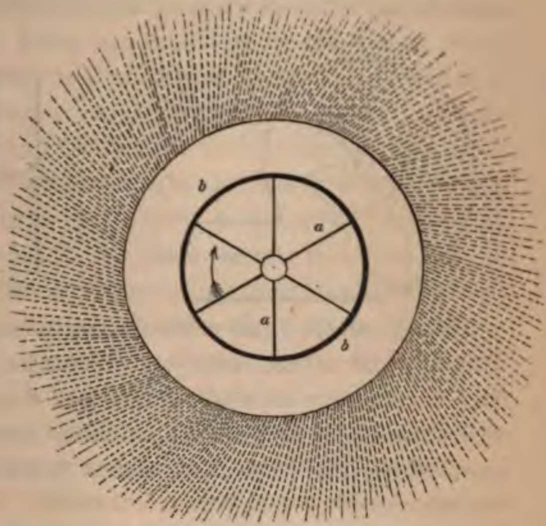


217. In Fig. 61, a different form of the fanner is represented, the air entering freely on each side of the blades a a throughout their whole extent, while the air is discharged by its circumfe-

rence throughout its whole extent. Fanners constructed in this manner are very powerful in discharging air. In Fig. 62, another view of the same fanner is given; the air is taken in at *a* and discharged at *b*.

Fig. 61.

Fig. 62.



218. If one side of the case within which the blades of the fanner are usually put be unscrewed, and the other be entirely closed (Fig. 63) on turning the fanner, if the number of revolutions be considerable, the air, as may be indicated by the movement induced in smoke produced near it, will be seen to move in the direction indicated by the arrows.

Fig. 63.

219. Instead of plain blades, others of a curved form may be seen in some fanners (Fig. 64), while the form of the curve is also a matter of importance, and is often varied according to the velocity with which the fanner is to be worked, and the special purpose to which it is to be applied.

220. If it be required to lead air into the centre of the fanner for any special purpose, the external casing should be made air-tight, so that no air can pass to the centre except by the course indicated by the arrows, and being discharged subsequently at the opposite side, air can be conveyed from the open orifice to any situation where it may be required. (Fig. 65.)

Fig. 64.

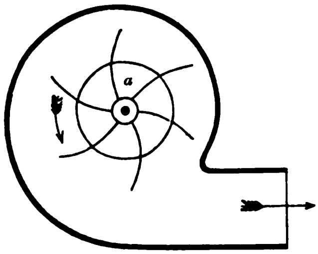
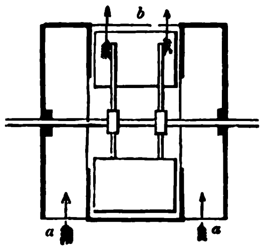


Fig 65.



221. In all the forms of the fanner, it will be observed, that it receives air at the centre and discharges it at the circumference. Fanners are made of all sizes, from the little blower used according to Mr Clarke's patent for household fires, to the large and powerful instruments such as cannot be worked without a steam-engine.

222. The larger the fanner, the greater the economy with which a given supply of air can be obtained. Small fanners, turned with great rapidity, as when they have from 1000 to 2000 revolutions per minute, usually make a penetrating and oppressive noise.

223. In using the fanner for ventilating purposes, it cannot be too particularly recollected that quantity of air is the object, not velocity, except in situations where the small size of the channels permitted renders it impossible to obtain the requisite quantity without great velocity. I have always found it most economical to use large fanners, moving with a comparatively slow velocity, and these have varied, in public buildings requiring a considerable supply of air, from ten to twenty feet in diameter.

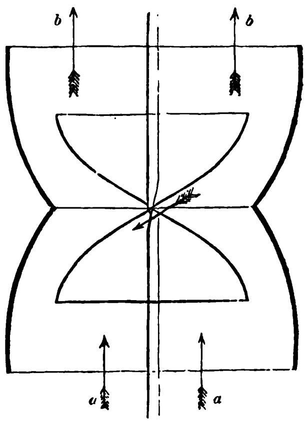
224. When the object is to produce a powerful blast of air, such as is required in an iron-foundry, very considerable velocity must be given to the fanner, which is made much smaller, and

to revolve from 600 to 1000 times per minute, producing, in this case, the noise which has been mentioned above.

THE SCREW.

225. In 1834, M. Motte received a prize for the application of the Archimedes screw as a substitute for the fanner; it has since been extensively used in Belgium, and also introduced in other places. Several years ago, Mr Combe, engineer to Messrs Marshall of Leeds, introduced the double-threaded screw as a ventilating instrument in their extensive establishment, working it with a steam-engine of six-horse power, and obtained very satisfactory results. At the same period, it is not a little singular, that another gentleman of the same name, M. Combes, in Belgium, devoted his investigations to the application of the screw in ventilating processes, and used in some of his experiments a form of screw similar to that employed by Mr Combe of Leeds, with whose invention and application of the screw he was as little acquainted as Mr Combe of Leeds was with the screw of M. Motte. When the ventilating arrangements of the Niger Expedition were in progress, I directed a model of a screw to be made, which was constructed accordingly, and propelled the air forwards or backwards according as it was worked; but the limited time I had at my disposal at that period did not permit me to have it made so as to test its power with other instruments. Within a more recent period, a patent has been taken out in this country for the single-threaded Archimedes screw, by Mr Day.

Fig. 66.



226. So far as I have seen as yet, I am inclined to give a preference to the screws used by Mr Combe of Leeds, and M. Combes

of Belgium, and others, in which two or more threads are used, as they are more equal in their action, and do not occupy so much space as the single-threaded screw. Fig. 66 shews one of the arrangements of this form of screw.

THE WINDMILL VENTILATOR.

227. It will be obvious, that, as the flat blades or vanes of a windmill are turned by the wind, so, if the wind be at rest, and the mill be put in motion by machinery, the vanes being left to rotate in the usual manner, they will move the air in contact with them. On this principle, various instruments have been constructed very different in details, several of which I have employed with advantage. Instruments of this kind have also been invented and used by Mr Clarke, Mr Imray, and Mr Combe of Leeds. Figs. 73 and 74 shew the form and plan of one of the various windmill-ventilators that are at present the subject of experiment. The figures preceding it (67 and 68, 69 and 70, 71 and 72) have been placed alongside of it, that those who have not attended previously to the construction and action of such instruments, may acquire a more precise idea of the manner in which they act, and the mode in which the air passes through them. It is scarcely necessary to add, that this must be considered as a general illustration, as numerous little eddies or local currents are developed in all of them, according to the proportions followed in constructing them, and the velocity with which they are worked. For example, though the screw propels the air onwards, as indicated by the arrows, the movement is strongest at the circumference; and, at the centre, on the side where the air escapes from it, an eddy or current in the opposite direction may be traced.

THE PUMP AND BELLOWS.

228. Air-pumps and bellows have long been used for the propulsion or extraction of air for ventilating purposes, and recently

they have been again recommended. At present, however, a

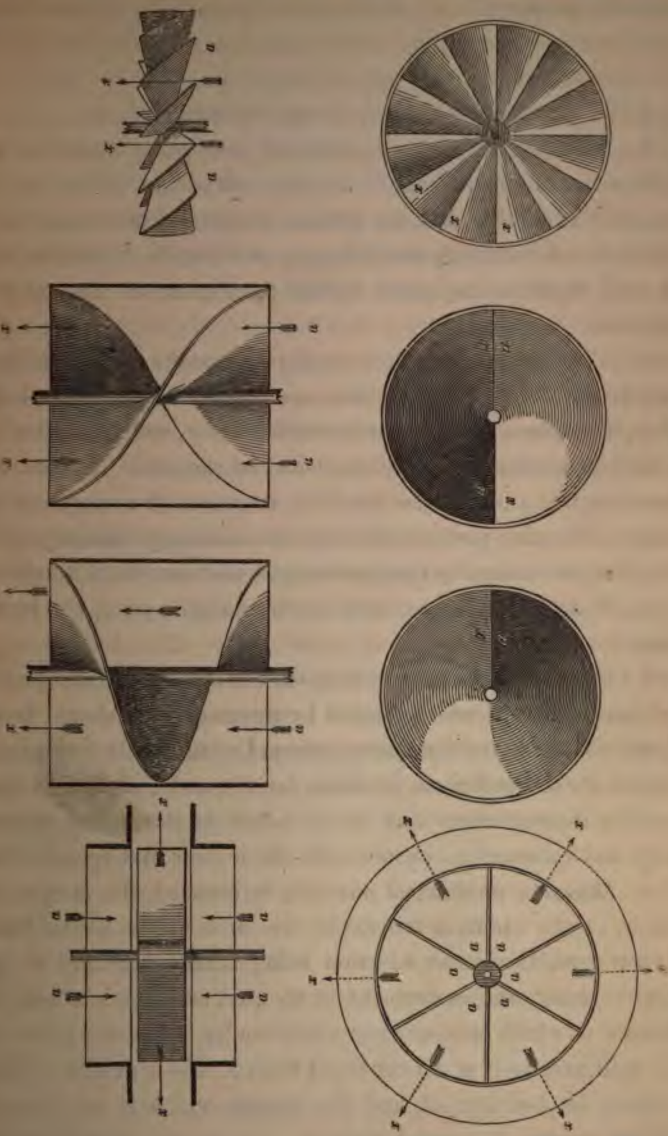


Fig. 67. Fig. 68. Fig. 69. Fig. 70. Fig. 71. Fig. 72. Fig. 73. Fig. 74.

preference is given generally to the fanner and the screw, the rotatory motion by which they are worked, and the continuity of

the stream which they produce, affording great advantages for ordinary purposes.

229. On the whole, then, it may be concluded,—

1. That, for a large proportion of ventilating purposes, the best mode of proceeding is to take advantage of the natural movements developed in the greater number of cases in vitiated air by heat for securing its discharge, assisting its exit by the force of such wind as may exist by the form given to the external aperture.

2. That when force is necessary to sustain a more uniform and determinate movement than can be secured in this manner, then, if the form of the structure admits of it, and particularly if a movement always on the ascent can be sustained, no power is so convenient and requires so little attention or management as a fire or heating power increasing the ordinary tendency of vitiated air to escape by the increased rarefaction which it induces.

3. That manual labour and winding weights are apt to be neglected.

4. That the use of instruments, such as screws, fanners, pumps, and windmill-ventilators, worked by steam-engines, should be resorted to only when the means referred to in the first two paragraphs are not sufficient, or too expensive and complicated from peculiar circumstances that do not admit of the introduction of large and commodious channels for the ingress and egress of air.

5. Where a mechanical power is introduced, the fanner, the screw, or the windmill-ventilator, are those which I should prefer for ventilation, the selection being made according to the form to which the instrument to be used must be adapted, the manner in which local circumstances render it necessary that the air shall pass to it or be conveyed from it, the area within which it must be constructed, and the amount which it may be considered proper to expend upon it. As to the details of construction, the numerous individuals who have been experimenting on these instruments, and who are still occupied with them,

both at home and abroad, hold out the promise, that, in a short period a very great mass of interesting information will be obtained. Many of the statements made are extremely discordant. The fanner with curved blades, for instance, which has been so strongly recommended by some experimenters, is affirmed now by Peclet to be little, if at all, better than that with plain blades, the complexity of the movements often induced by the curves counteracting the advantages they otherwise present. In all the experiments which I have made upon fanners for ventilating purposes, the construction of which I had not arranged, and to which my attention had been directed, I have almost invariably found that they were too small to work economically. A very common error also is to suppose that a fanner is more powerful in its action in exhausting than in propelling air. A moment's consideration will shew that this is a mistake, as a fanner only exhausts what it does propel. If well made, then, its power of exhaustion and propulsion must necessarily be equal. The error has probably arisen from fanners having on some occasions been acting with the assistance of a current when they were exhausting, and against the current when they were propelling; or from some inequality in the size of the attached communications, which, from their magnitude, form, or structure, necessarily rendered the exhaustion and the propulsion unequal, the connections for the one purpose presenting obstacles which the other did not.

CHAPTER III.

ELEMENTARY ILLUSTRATIONS OF VENTILATION.

230. In the last chapter, several illustrations are given with the view of shewing more particularly some of the varied movements that may be induced in air by the action of heat, according to the circumstances under which it operates, and the mechanical powers most available for ventilation, where neither natural ventilation nor the application of artificial heat can be introduced. In this chapter, the elementary diagrams given are intended to explain some of the more common movements of air that require attention, such as are continually referred to in ventilating operations. In all these illustrations, the temperature of the air is supposed to be below that of the human body (98°), where the reverse is not stated.

231. The first figure refers to the movement of air within any room or apartment, all communication with the external atmosphere by doors, windows, flues, chimneys, or any other channel, being supposed to be entirely prevented.

232. Whenever any elevation of temperature is produced,

Fig. 75.

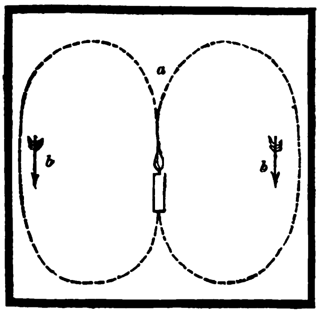
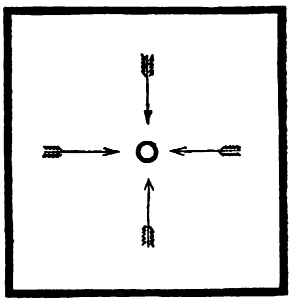


Fig. 76.



as in a room with a candle in the centre, immediately a stream of

warm air ascends from it, and colder presses towards it from every side. Fig. 75 shews the general progress of the currents induced, looking to a section of the apartment. Fig. 76 indicates the currents on plan.

233. If a mass of ice be substituted for the candle, the currents are reversed; air descends on every side from the cold ice, Fig. 77, and the currents on the floor run outwards, Fig. 78.

Fig. 77.

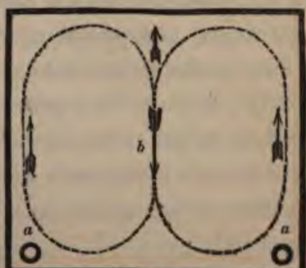
Fig. 78.

234. In each of these cases the currents above and below are always observed in the opposite direction; with the candle they are towards the centre on the floor, and from the centre at the ceiling; with the ice the movement is the reverse both above and below.

235. All local sources of heat and cold tend invariably to produce similar effects, though the curve described may be varied indefinitely as the air is still, or subject to considerable fluctuation.

Fig. 79.

Fig. 80.



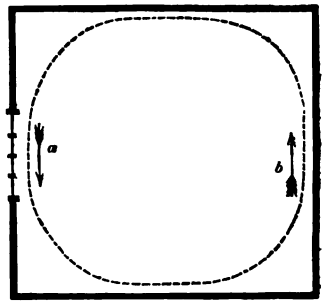
236. *A stove in the* centre of any room produces a move-

ment such as the candle does. But if placed at one side, Fig. 79, the air warmed by it ascends on that side, and a corresponding amount of air descends on the other side. If a stove be placed on either side, or a hot-water pipe be carried round the skirting board of any room, the movements then proceed as in Fig. 80, unless cold windows, walls, or doors, modify the movement.

237. A number of people in the centre of any apartment, determine similar ascending currents from the centre which they occupy. In a practical point of view, every individual affects the movement of air in the same manner as a stove; and numbers, when aggregated in different places, produce an extreme complexity of currents, sometimes reversing entirely the course of movement desired.

238. A window in cold weather is always a source of descending currents, as in Fig. 81, an ascending movement taking place on the opposite side. This descending current is altogether independent of any influx of cold air that may or may not accompany it, according to the care with which it has been fixed. But even where the window has been rendered absolutely air-tight, it will be obvious, that, if the glass be maintained at a low temperature by the external atmosphere, the air in contact with it must become cold and dense, falling accordingly, and producing a continuously descending current, so long as the glass is colder than the rest of the apartment.

Fig. 81.



239. If there be a general movement of air from one end of the room to another, determined by a fire or any other cause, the descending current is not always directly under the window, but more or less at one side, according to the inclination of the current.

240. Such descending currents are a common source of dis-
t and disease, particularly rheumatisms, colds, and in-

flammations, sometimes terminating in death. They should be studiously avoided, by all who may be apt to be exposed in situations where they are likely to occur, as in halls and galleries, in churches or other places with large windows. The extent to which they prove a source of annoyance is extreme. No cause of complaint is more frequent in public buildings, and in all situations where large windows are introduced. I have seen corridors where nearly a thousand square feet of glass were at a temperature below 32°, thickly covered with hoar frost condensed on the interior surface, and pouring down a continuous stream of ice-cold air, while the general temperature of the rest of the corridor varied from 60° to 70°.

241. When there are windows on either side, as in a church, the cold air is precipitated on both sides, Fig. 82. But when

Fig. 82.

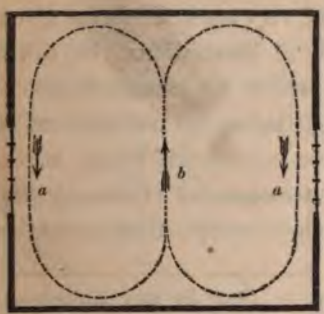
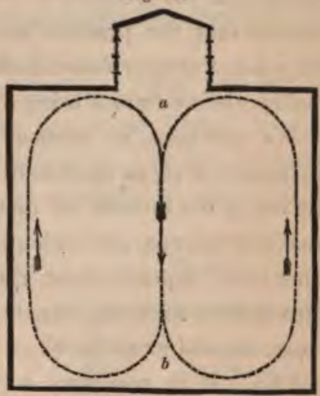


Fig. 83.



there is a large window or lantern in the ceiling, the currents then take an opposite course, Fig. 83. Such lanterns have often proved very offensive in many law courts, the briefs of the barristers being literally covered at times with the condensed exhalations dropping from the cold glass of the lantern, where proper arrangements have not been made for carrying them off.

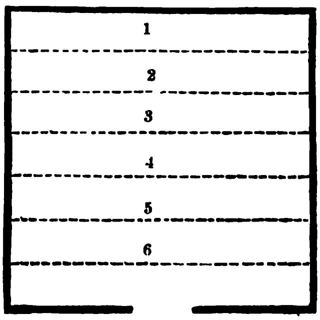
242. The evils arising from such descending currents may be partially overcome by the local introduction of warm air, when this is practicable, and much more effectually obviated by double windows. It would probably be a source of permanent economy were all public buildings with large windows, and in daily use in

winter, provided in this manner; much less fuel would then be requisite to warm them in coldweather. But the expense will probably, in this country, be a barrier to their general introduction, the winter not being so long, nor the cold so intense, as in those countries where they are almost universally adopted. Where double windows are introduced, the fittings should be made absolutely close, as if any of the external atmosphere should reach to the interior window, or any of the air pass from the chamber between the windows into the apartment, the use of the double window will be greatly, if not entirely impaired. A very small interval between the windows is sufficient to produce a great effect, but the nearer they are to each other, the less the benefit derived from the double glazing. At Berlin I have seen houses where they had the opportunity of placing the windows at the distance of 18 inches from each other, and I was assured that the practice was advantageous. But even where the window is provided with double panes of glass, the expense of double window frames being avoided, very marked relief is given.

We now come to another series of illustrations, viz., to the movement of air in apartments in which the communication of the air in the interior of these apartments has not been cut off from the external atmosphere, these movements being, at the same time, dependent on the relative gravity of the air, and unconnected with any impulse it might receive from any other cause, natural or artificial.

243. It is necessary to premise, that in any apartment having any flue or aperture below, (Fig. 84), no movement whatsoever ensues, if the temperature in that apartment be superior to that of the atmosphere below; the successive strata or layers of air above tend to retain their relative position. In the same manner, 'f any opening be made in the ling of an apartment, the suc-

Fig. 84.



cessive layers still remain in their relative position as they are numbered, no movement nor interchange takes place between them and the external atmosphere, if the air, in this case (Fig. 85), be heavier, *i. e.* colder, within the apartment

Fig. 85.

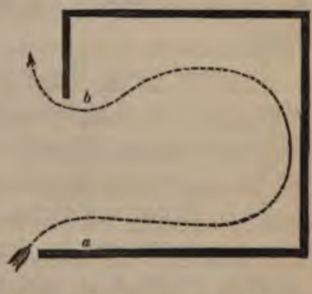
Fig. 86.

than without it, and there be no wind or other mechanical cause to agitate the air.

244. If, however, the opening be *below* (Fig. 86), but the temperature of the air under the apartment higher, then an interchange proceeds as the arrow indicates. A similar movement is induced (Fig. 87), when the aperture is above, if the

Fig. 87.

Fig. 88.



temperature within be higher than that of the external atmosphere.

245. Again, if we look to doors and windows, similar phenomena may be traced. Fig. 88 shews an external atmo-

sphere at 50° displacing all or the greater portion of the warm air in an apartment at 60°, excepting a portion above the level of the door. Above that level, every thing remains comparatively stagnant. Fig. 89 illustrates the movement of an external

Fig. 89.

Fig. 90.

atmosphere at 60°, entering and displacing entirely the colder air in an apartment at 50°; the door being open.

246. Again, in Fig. 90, the movements are given that ensue between an external atmosphere at 50°, entering an open window, and entirely displacing air at 60°. Lastly, Fig. 91 indicates warm air entering by a window at 60°, leaving the lower part of the room still full of air at 50°, while all the cold air above the level of the sill of the window has been displaced.

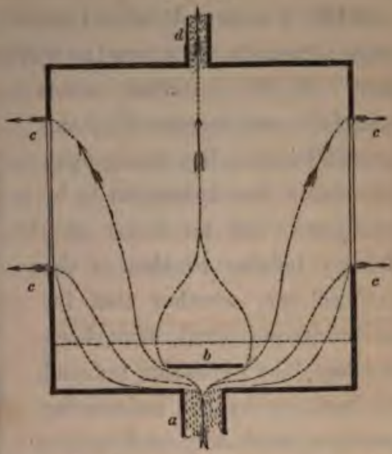
Fig. 91.

In considering the movement of air when fluctuations of pressure ensue, it is desirable to bear in mind, that, in all ventilating operations, the apartment ventilated must be supplied with air by a Plenum, by a Vacuum, or by a Mixed Movement.

247. Plenum Ventilation (Fig. 92). When air is blown into any apartment by the force of the wind, or by any mechanical power, it is said to be ventilated by a *plenum movement or impulse;* and, when in this condition, it is filled to such an extent with air, that not only all the appointed channels for the egress of air, but also all crevices at doors and windows, and all flues or other apertures, discharge air exter-

nally from the superfluity within. These circumstances, and the certainty of introducing, without mixture, the air that is considered best, form the great peculiarity of plenum ventilation, which can be sustained only by the constant use of machinery, as the influence of wind is, in general, too uncertain and unequal in its operation for this purpose, though its power is frequently used advantageously for a plenum impulse, when a more certain provision is not secured.

Fig. 92.



248. Some writers have recently advocated the opinion, that a plenum movement is advantageous, not only from the unity of atmosphere which it developes in the apartment into which it is introduced, but also from the superior advantages which a dense atmosphere is supposed by them to possess over that which is comparatively attenuated. The mere density of the air supplied in any ordinary building, cannot, however, I apprehend, be a matter of any real consequence, as whatever density may be given to air by machinery, or in the leading air-channels immediately attached to the pneumatic machine employed, it is not practicable to communicate any considerable increase of density in any apartment at a reasonable expense, so long as communications with the external atmosphere by doors or otherwise are not placed on a very different footing from what they are at present; nor, when the fluctuations of the barometer are so considerable from day to day, can it be supposed that any action less in intensity than what is continually produced by this cause, can be likely to exert any very sensible effect, while, at the same time, it is not unfair to con-

clude, that the pressure which actually obtains at the surface of the earth, must be considered the best for the maintenance of health and strength both of body and mind.

249. VACUUM VENTILATION. Fig. 93. This comprises all cases of ventilation where the discharge is effected by the pressure of the external atmospheres,—not increased by any artificial means, but acting upon air within the apartment to be ventilated, this air being of a density inferior to that of the external air, whether that inferior density shall have been developed by expansion induced by heat, or by the exhausting power of machinery—of machinery which, if employed to blow in air, would have produced a plenum impulse, but which, being applied directly to the vitiated air to be extracted, is necessarily accompanied by a diminished density in the air upon which it acts.

Fig. 93.

250. A chimney is ventilated on this principle, the diminished pressure arising from the expansion of the air within it making it give way before the pressure of the external air. Air rushes into all ordinary apartments only when there is a want of resistance. If the air in them be not permitted to escape, none can enter unless forced by the application of increased pressure. *Vacuum Ventilation*, or, as it is sometimes termed, Ventilation by the *Vacuum Impulse*, accordingly, involves the necessity of a free discharge of air from the apartment ventilated to such an extent, that wherever a door, window, or other aperture shall be opened, air is forced in there by the pressure of the external atmosphere. The accompanying figure (93) illustrates this variety of ventilation, and its more ge-

neral adoption may be attributed to the comparative simplicity and economy of the means by which it may be sustained.

251. In MIXED VENTILATION, both the plenum and vacuum movement may be traced; the force of the air when it is introduced being such as to prevent the action of offensive currents at crevices or apertures, at doors or windows, while the power of the aperture, or discharging shaft through which the vitiated air escapes, is superior to the duty it has to perform; in its vicinity, therefore, there may be a tendency to exhaust, though, at other places, a plenum rather than a vacuum impulse may predominate.

252. In considering these varieties of ventilation, it will be evident that the perfection to be aimed at is the maintenance of such an equal movement as shall give an ample supply of air, and that the ingress shall bear such a proportion to the egress, that no offensive lateral currents shall be induced between one apartment and another. From the minute and delicate circumstances that affect the equilibrium of atmospheric air, this is unattainable, with mathematical precision, in practice; nevertheless, it should be the constant aim of the ventilator to approximate to it as nearly as possible, according to the peculiarity of circumstances which he may have to meet, and the power of adjustment placed at his disposal.

253. Those who advocate plenum ventilation, too frequently trust entirely to the machinery with which the air is supplied, both for its introduction and subsequent expulsion. Few circumstances contribute more to produce dissatisfaction in ventilating arrangements, than the want of a proper efficient channel for the escape of vitiated air. Where this is not to be met with, fresh air may be blown into one room, but vitiated air from it too often passes into another. And if doors and windows be well closed, no discharge may then be accessible but by the chimney. But if this be at a low level, the fresh air blown in is more apt to escape than the vitiated air above.

The difficulty may be surmounted in part by opening windows, but that leaves the apartment subject to the operation of local currents, if the window be opened more than is absolutely necessary; while, in crowded situations, it exposes the apartment to offensive noise, and, more or less, to the uncontrolled influence of the external atmosphere.

254. It may be concluded, then—

I. That a discharge from the loftiest part of the building to be ventilated should always be provided in the first instance, so as to secure the full force of those natural movements that are sufficient for ordinary ventilation.

II. That means of increasing the force of natural ventilation should be provided in all public or other apartments liable to be crowded with many persons.

III. That where the above means, and double doors, and other precautions, do not, from the constant ingress or egress, prevent currents, machinery should be introduced to sustain a sufficient plenum movement to control them, and to supply the air it may be intended to give, without any intermixture from other sources.

IV. That peculiarities of structure in the external atmosphere, and in the purposes to which the building to be ventilated may be applied, require, in many cases, special modifications.

V. *That all apartments where the ingress of fresh air is deficient, though worked by powerful exhausting shafts, or where the egress is deficient or uncertain, though ventilated by powerful machinery*, give unequal and unsatisfactory results.

255. In arranging openings for the ingress and egress of air, the general direction of the wind, local impurities, and the influence of adjoining buildings, require attention. It is a great point to be able to command the assistance of the external atmosphere either in determining the ingress or the egress of air, and to adjust necessary openings in such a manner that they shall not be subject to down-draughts from surrounding buildings, when

the wind strikes upon them, and is reflected so as to oppose the ingress or egress of air.

256. It is equally important to supply pure air from an eligible source, free from the contaminating influence of drains, of the surface of the street, of the smoke line in the vicinity, and from any local source of impurity.

257. Fig. 94 gives a general illustration of mixed ventilation, the valves and apertures, *a a*, being set so that the wind shall supply abundance of air, by a plenum impulse through one, and also contribute to the discharge by favouring a vacuum impulse

Fig. 94.

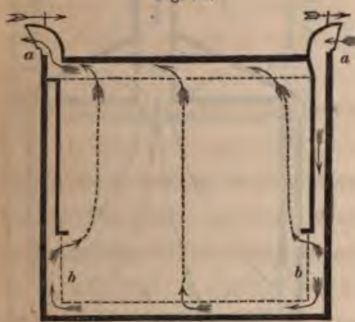
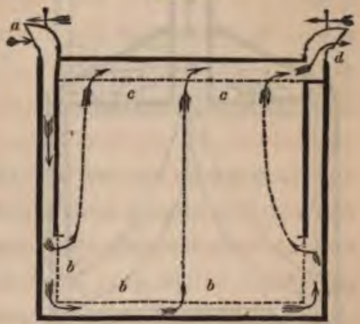


Fig. 95.



at the other. In this figure the wind is supposed to be *from the west*.

258. Fig. 95.—The same building, shewing the same gene-

Fig. 96.

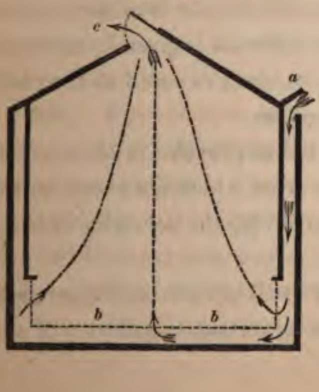
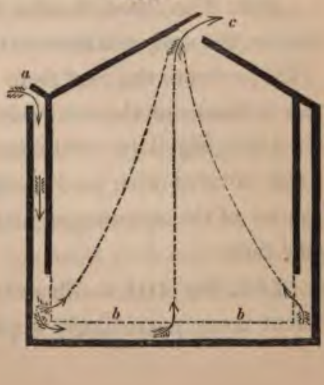


Fig. 97.



ral effects produced by an *easterly* wind, the valve being altered so as to secure this object. In both cases the air enters with diffusion at *b*.

259. Fig. 96.—A more simple arrangement for producing the same effect, as is represented in Fig. 90; *the wind being from the west.*

260. Fig. 97.—The same apartment, with the valves arranged for an *easterly* wind. The two valves, *c c*, on the ridge, may be placed opposite each other.

Fig. 98.

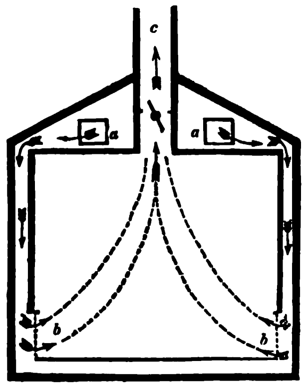
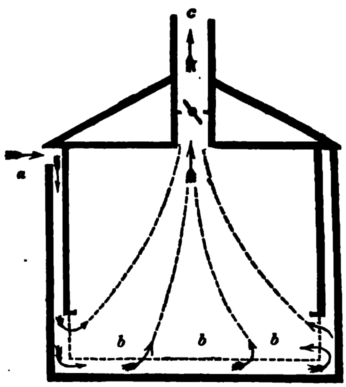


Fig. 99.



261. Fig. 98.—The air is received by openings in the gable and under the roof. Diffusion is given by a deep dado. The air escapes by a central channel, and the discharge is regulated by a valve.

262. Fig. 99.—Similar to 94, but the air is admitted by a flue in the wall, and more extensive diffusion is given by the floor. This prevents the roof from being so much exposed to the chilling influence of the external atmosphere.

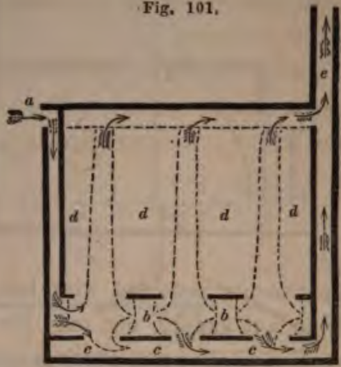
263. Fig. 100.—Similar to 94, but provided with a central table covered with perforated zinc, from which air passes to the centre of the apartment, without involving the necessity of using the floor.

264. Fig. 101.—Illustration of a still more extended arrangement more particularly applicable to museums, galleries of art,

and exhibitions, where the works exhibited are subject to injury from causes that appear trifling at first, but whose continued

Fig. 100.

Fig. 101.



operations renders them powerful, and where a crowd and a frequent promenade necessarily subject them greatly to the alternate influence of dust and moisture. By the arrangement shewn here, all dust is carried downwards at once by the descending current determined from a perforated floor, while the moisture of the breath, the carbonic acid, and also the exhalations from the body, are carried away, in the usual manner, by the ceiling. It is scarcely necessary to remark, that the different fresh air chambers, *b b*, are made so as to communicate with each other, while from *c c c* and *d d d d* nothing but vitiated air is carried away. A power in the discharging shaft produced by heat or machinery is desirable, according to the extent to which the rooms are crowded.

265. Fig. 102.—An arrangement introduced into several schools and private rooms, by which fresh air is permitted to enter under the window.

266. Fig. 103 shews the general progress of air from a perforated zinc skirting board, freely supplied with air to a perforated cornice, where it is discharged, the curve being infinitely varied, according to the peculiarities of each apartment.

267. Fig. 104 illustrates the important position that in all

Fig. 102.

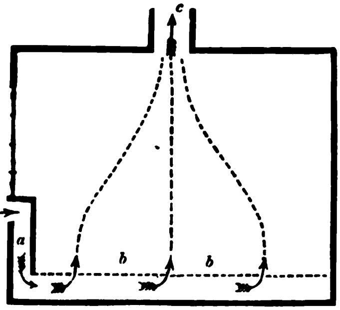
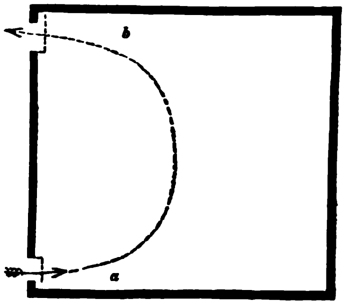


Fig. 103.



apartments provided with low fire-places, there should be an abundant supply, not only for the fire-place, but also for that portion of the room which is above it, a discharge being provided at the cornice, or at some other convenient site above the zone of respiration.

Fig. 104.

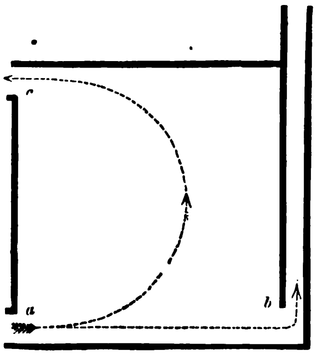
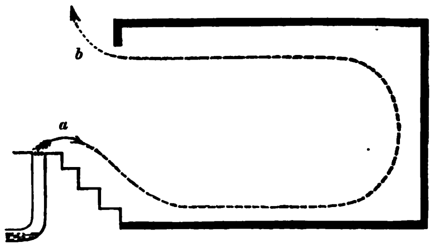


Fig. 105.

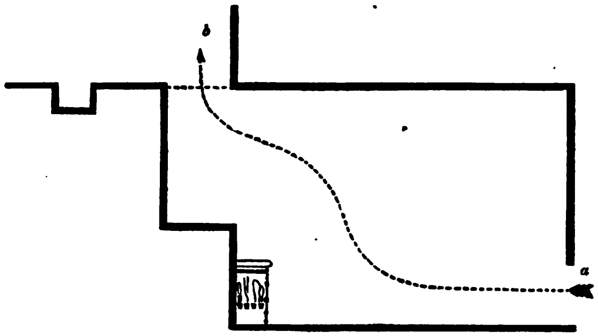


268. Fig. 105 shews the progress of a current of air from the surface of the street, and from a drain adjoining a cellar, where, as it is ventilated by the door, the supply is necessarily taken where the air is of a very bad quality, and loaded with putrescent emanations.

269. Fig. 106.—General progress of offensive air from un-

derground apartments, as kitchens, and numerous small workshops or factories in streets, the air passing upwards and escap-

Fig. 106.



ing by the pavement, to the annoyance of passengers, when not discharged by special flues.

270. Fig. 107.—Scheme, shewing the movements of the air where two apartments are supplied from the same source, and discharge into the same channel. In all such cases, the means

Fig. 107.

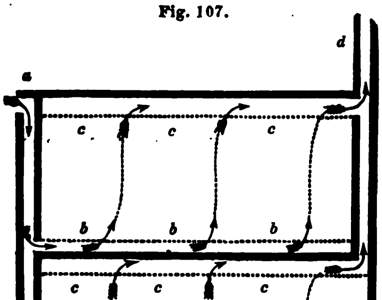
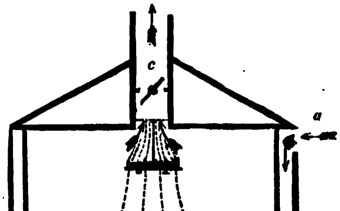


Fig. 108.



of supply and discharge must be ample, otherwise the results are unsatisfactory.

271. Fig. 108.—In any apartment crowded with people, if the ingress and egress of the air be unrestricted, the movement of the air is greater and greater the higher the temperature communicated to the air. The introduction of a lamp under the ventilating aperture increases greatly its power of discharge, and produces, in an empty room, a similar effect.

272. Fig. 109.—A gas-lamp, a candle, an oil-lamp, a jet of steam, or a case or series of pipes filled with steam or hot water, or a fire put into any fire-proof flue, shaft, or chimney, acts in a similar manner.

Fig. 109.

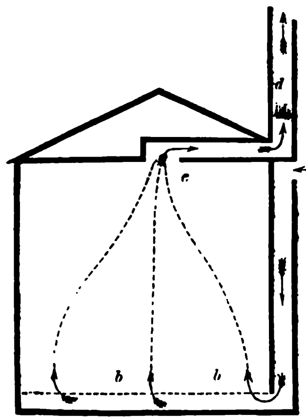
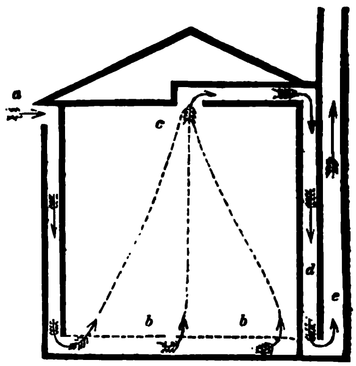


Fig. 110.



273. Fig. 110.—Where circumstances do not admit of the heat being applied with safety above, the arrangement shewn in this figure may frequently be adopted with advantage. The position of the fire, lamp, or steam-pipe at *e*, is so far disadvantageous, in so much as there is a loss of power wherever it is necessary to draw down heated air from the roof or ceiling of any apartment; but this, in general, especially where a fire is to be used, is not so important as the facility of attendance, and the great altitude of the warm chimney which is then so easily commanded.

274. Fig. 111 shews the method of sustaining a descending current, an arrangement in opposition to the natural movements of vitiated air, but nevertheless very important in peculiar cir-

cumstances, as with some lunatic patients, and in some operations of art. Heat is commonly sustained in the shaft for this purpose.

Fig. 111.

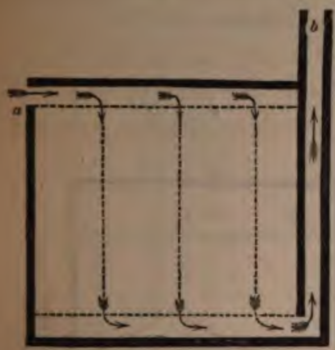
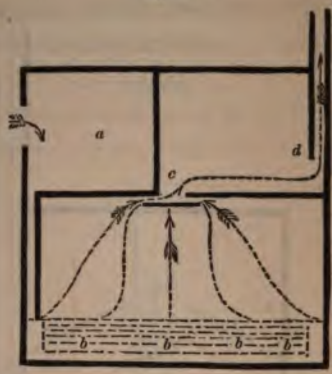


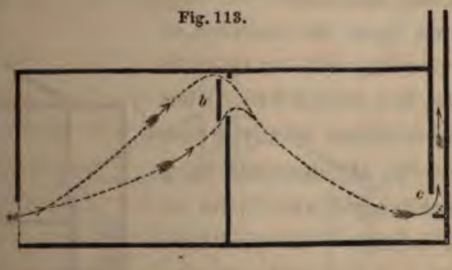
Fig. 112.



275. Fig. 112.—Three contiguous apartments connected for a temporary purpose, so that fresh air is supplied from *a* to *b*, diffused at *b*, and withdrawn by a powerful fire in *c*.

276. Fig. 113.—Another arrangement by which one room *c*, not used for any other purpose, is made, with the assistance of a common fire, to ventilate another room *b*.

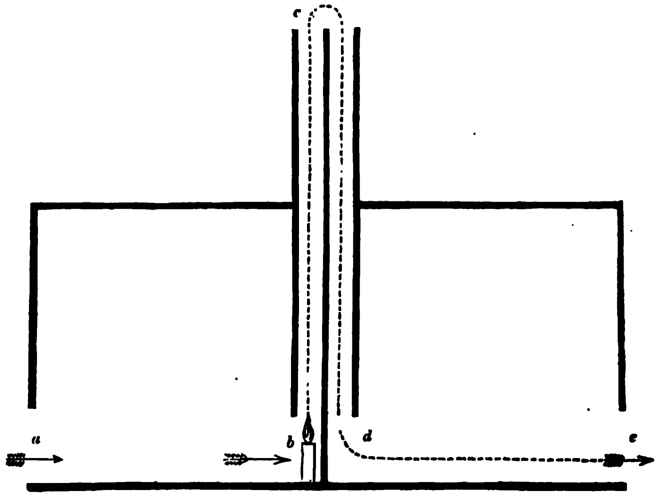
Fig. 113.



277. Fig. 114.— When a door or passage *e*, is the only means of supply for a large fire in another room, this fire often draws air from any adjoining apartment *d*, which then smokes offensively, and, in calm weather, air often escapes from the chimney *b*, darting at once down to *d*, through the external atmo-

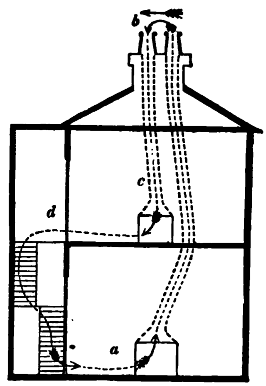
sphere, the air entering at *a*, being, in this manner, ultimately conveyed to *e*.

Fig. 114.



278. Fig. 115.—Nothing is so common a cause of smoke as an insufficiency in the amount of air supplied to any apartment, as to *a*, when it draws upon the staircase *d*, and if it be provided with an air-tight external door, it is supplied by *c*; but if *c* also be destitute of any proper source of supply, air descends to it through the chimney *b*, and, if the atmosphere be calm, or if the wind blow in the direction indicated by the upper arrow, then the smoke from *a* may be seen passing to *b*, forming, in this manner, a complete circle. It is evident also, that, under these circumstances, a small fire in *c* will be overpowered by a large fire in *a*.

Fig. 115.



279. Fig. 116 illustrates a similar action with three apartments, the kitchen-fire at *a* being supplied through *d* with air from *c* and *c*.

280. Fig. 117 shews the position of a fanner in the roof of an apartment to be worked there, so as to induce ventilation with machinery by exhaustion, *i. e.* by the vacuum impulse.

Fig. 116.

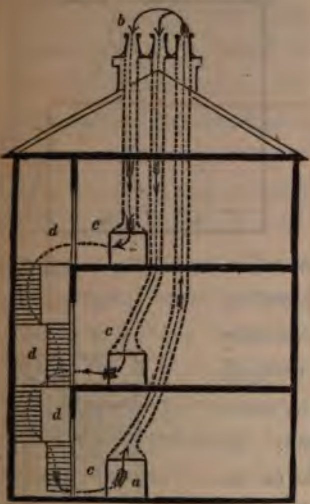
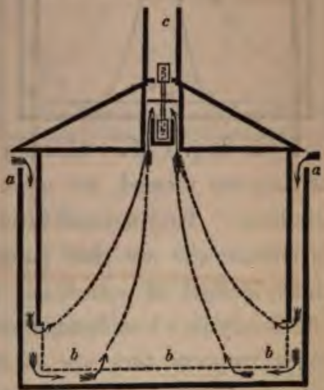
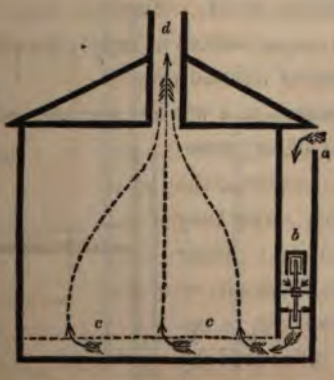


Fig. 117.



281. Fig. 118 indicates the position of the same instrument

Fig. 118.



when used to ventilate by propulsion, or by the plenum impulse.

Figs. 119 and 120 shew the position of the screw, when employed in parallel circumstances.

Fig. 119.

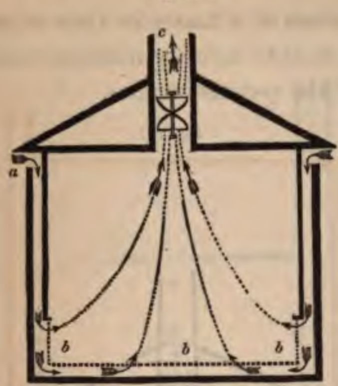
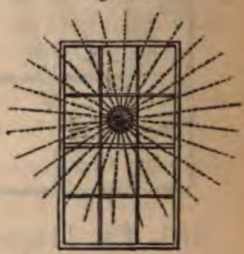


Fig. 120.

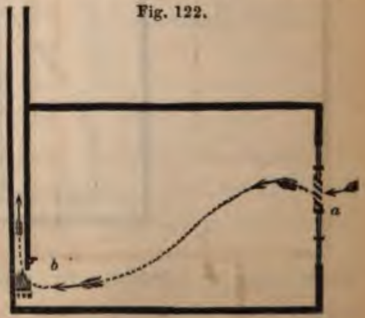
282. Fig. 121. Circular moveable, or rotatory ventilators, as they are termed, are often placed in windows. They act well in so far as they distribute the air that passes through them, instead of permitting it to move offensively in a less divided stream. In other respects they are of little or no value. When extremely small, they rather impede than assist the free progress of the air that passes through the space they occupy, by the force required for turning them. Further, they will be found in general rather to act as sources of supply for the ingress of fresh, than for the egress of vitiated air.

Fig. 121.



283. Glass louvres in a window are certainly very convenient in giving a supply of air, somewhat in the same manner as the rotatory ventilator, while they are free from noise. Their tendency to admit fresh air, or to discharge vitiated air, is necessarily greatly influenced by the circumstances under which they are exposed. Air may pass directly from them to the

Fig. 122.



chimney, as is represented in the figure; or air may enter by the lower part of the louvre and escape by the upper part, or *vice versa*, when the chimney is not in operation. Their greater size renders them in general much more effective than the small rotatory ventilator.

Fig. 123.

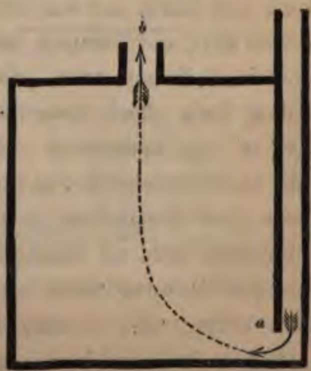
284. Fig. 123.—A chimney supplied with air from a channel so near it, that little or none of the air by which it is fed is drawn across the apartment to the fire, leaves the apartment free from many of those draughts and currents that are common to all ordinary rooms with fires, and which pass in general between the window and the fire-place, or the door and the fire-place.

285. Fig. 124.—A flue in powerful action frequently draws down vitiated air from any aperture in the ceiling intended for its escape, in the same manner as may be observed with the glass louvre.

286. Fig. 125.—If the ventilator be in powerful action, it

Fig. 124.

Fig. 125.



may overcome the chimney and draw air from it, if there be no sufficient ingress for the supply of both.

287. Figs. 126 and 127 indicate the progress of warm air admitted into any room having only an imperfect discharge near the floor, the hot air at once advancing to the ceiling, and a portion below escaping at *b*, as each successive portion, direct from the heating surface, reaches the ceiling. The temperature there may be very considerable, while severe cold prevails below. The successive numbers indicate the successive portions of air which have descended from the ceiling.

Fig. 126.

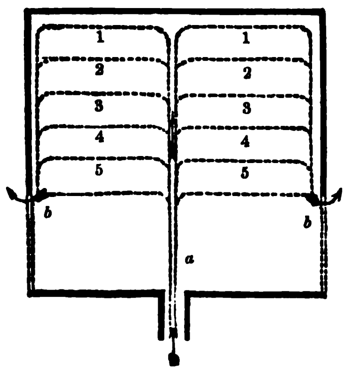
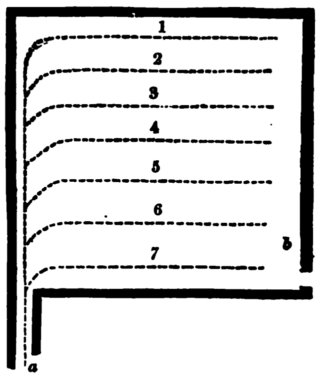
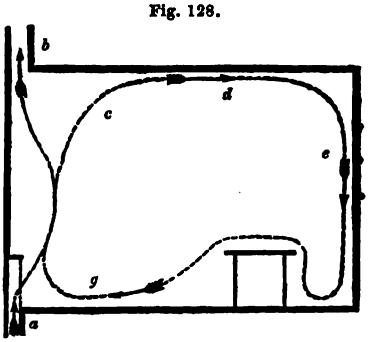


Fig. 127.



288. Fig. 128 indicates the movements of air in a public office, where different individuals suffered considerably from the state of the atmosphere. The fresh and warm air was admitted at *a*, and escaped, almost immediately, at *b*, producing little effect upon the rest of the apartment. A cold window at *e* proved at the same time a cause of great annoyance, cold air descending from it upon those who were below, while a very imperfect and sluggish circulation ensued, as indicated by the arrows.

Fig. 128.



289. Fig. 129.—Two apartments connected together by a

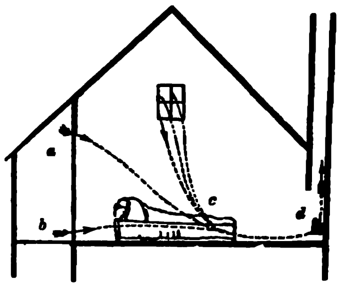
Fig. 129.

passage, and so situated that when air passes into one *a*, the wind being easterly, it receives the first impression of the fresh air, and nothing but an atmosphere of very inferior quality passes into the other *c* by the passage *b*; but when the wind is in a different position, viz. westerly, the condition of these two apartments is entirely altered, the fresh air now entering first into the apartment which previously received the vitiated air, so that, as the wind changes, they alternately receive fresh or vitiated air. The passage at *b* is omitted, that the progress of the currents may be more distinctly seen.

290. Fig. 130 shews the ordinary progress of air in a sick chamber, fresh air entering as usual at the minute openings above and below the door, and passing onwards along the floor to the fire, while the patient, resting at a higher level, derives little or no benefit from the movement, being still enveloped in the warmer atmosphere, charged with watery vapour and carbonic acid, and frequently passing in consequence a restless night, when he might otherwise enjoy a refreshing sleep.

Fig. 130.

Fig. 131.



291. Fig. 131.—This represents a single apartment in an attic, where a patient, resting on some straw, was subjected to the influence of cold descending currents, both from the window and the door. The illustration was taken from a miserable attic in one of the poorest houses of the Canongate in Edinburgh.

292. Fig. 132 shews a very common arrangement, by which patients suffer from the precipitation of cold air, particularly should they be asleep at the time, and under the influence of a sudorific; this downward movement of the air may be strongly induced, by cold glass, though absolutely air-tight. See 238.

Fig. 132.

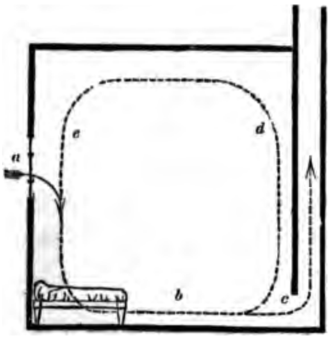
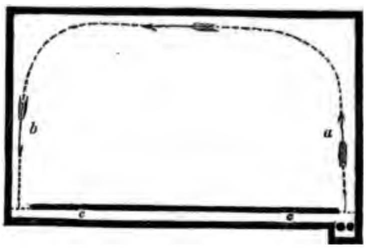


Fig. 133.



293. Fig. 133.—This figure points out the manner in which some places are continually subjected to a return of the same atmosphere, there being no openings permitted either for the ingress of the fresh or the egress of the vitiated air. The hot apparatus maintains a perpetual movement, the same air returning indefinitely to the warm apparatus. Such a mode of proceeding may be very economical and very desirable, so long as the apartment is unoccupied, with the view of heating both the

air and the walls; but it ought to be discontinued and fresh air permitted to enter at one aperture, while the vitiated air is discharged by another, whenever it begins to be occupied.

294. Fig. 134.—This figure illustrates another variety of bad ventilation, which is very commonly met with in numerous situations. I have noticed it particularly in some churches and hospitals, where there may be a considerable aperture between the ceiling and the roof, though, after the vitiated air may have passed the ceiling, there are no means for enabling it to escape from the roof; it returns, accordingly, on one side or other, as accidental circumstances may determine.

Fig. 134.

295. Fig. 135 shews the plan, and Figs. 136 and 137 the

Fig. 135.

Fig. 136.

Fig. 137.

longitudinal and transverse section of a large apartment under the Assembly Rooms, Edinburgh, which was fitted up in a

temporary manner as an oxihydrogen microscope and polariscope-room, during the exhibition of arts and manufactures. The fresh air was taken from the external atmosphere at *a*, entered the room diffusively on three sides at *b*, *b*, *b*, and was discharged by a mechanical power worked by hand-labour at *x*, the vitiated air proceeding throughout the whole extent of the deep porous cornice *c*, *c*, *c* to *x*. These arrangements were completed in a few days from the time when they were commenced, and gave accommodation to crowded audiences, which continually succeeded each other throughout the day during the progress of the exhibition, consisting of, in general, from six to eight hundred persons.

296. These illustrations will enable the beginner to study some of the more important points connected with the movement of the air in different ventilating operations. He must bear in mind, however, that the movements of the air are much more complex in actual practice than have been represented. The object in this chapter has not been to enter into extreme details, but rather to point to results, and after these have been rendered familiar by frequent examination, he should endeavour to trace the currents that are produced in different apartments, and verify them by his own observation. This is most easily effected by using an exceedingly minute thread, which is inclined in any direction by the slightest movement in the atmosphere, or by producing a little smoke with a very small coil of brown paper, taking care to use no more than is absolutely necessary, so that any error from the heat of the paper may be reduced as much as possible.

CHAPTER IV.

GENERAL REMARKS ON GASES.

297. Extreme mobility, compressibility, and elasticity, form the great and leading mechanical properties by which Atmospheric Air and other gases are distinguished.

298. Though not perceptible in general, they possess, equally with solids and liquids, all the essential properties of matter, while their extreme tenuity renders them susceptible of the most delicate impulse. No balance is so nicely adjusted as the pressure of one portion of air upon another. In a perfect calm, aerial bodies may rest quiescent upon each other, but the most trifling possible impulse, or change of specific gravity induced by heat or pressure, is immediately accompanied by motion, and the production of endless varieties of currents, or eddies, whose course is perpetually modified by the circumstances under which they are produced. Practically speaking, the air is scarcely ever absolutely quiescent on any part of the surface of the globe, though, in particular regions, at certain periods of the year, it may be considered comparatively at rest. The most frequent changes are observed in those districts where the alterations of land and water, hill and dale, and other causes, favour the production of unequal temperatures.

299. Natural and artificial ventilation depend upon the extreme mobility of the air, and accordingly, every power or agent that can induce any movement in air, may be rendered available for the purpose of ventilation. The particles of air, all over the globe may be regarded as pressing on each other to a certain extent, and perpetually tending to attain a quiescent position.

which would ultimately terminate in a silent and death-like calm, were it not prevented by the inequality of temperature induced at different parts of the earth's surface by the action of the sun, vegetation, animal life, and by volcanic and other sources of chemical and mechanical changes, particularly electricity.

300. The pressure which air or gases of any kind exert at the surface of the earth arises from their weight. The human frame and all other objects there, are subjected to the pressure of the superincumbent atmosphere in the same manner as a diver at the bottom of the sea is subjected to the weight of the column of water above him. We live at the bottom of an aerial ocean.

301. This pressure varies at different times, as indicated by the barometer. The aerial ocean or atmosphere is subjected to currents, and its height to fluctuations, in the same manner as the waters of the globe.

302. The atmosphere, at the level of the ocean, according to the standard commonly adopted, presses on the different surfaces mentioned with a force equal to the weights indicated below.

On one square inch, with a weight of .	14.6 lbs.
On one square foot, ...	2102.4 ...
On one square yard, ...	18921.6 ... or 8.45 tons.
On one square mile, ...	26166000.00 tons.

303. Every part of a still atmosphere is in equilibrio, each particle being equally pressed in every direction, and every body existing in that atmosphere is pressed on all sides with a weight of 14.6 pounds on every square inch at the surface of the earth, the thermometer being at 60°, and the mercury in the barometer at 30 inches.

304. In ascending from the surface of the earth, the pressure diminishes, and also the density of the air. In the more elevated regions of the atmosphere, the tenuity of the air must be extreme. If the air were all of equal density with that at the surface of the earth, or homogeneous throughout its whole extent, an altitude of 27,460 feet (upwards of five miles) would be required to produce a pressure of 14.6 pounds on a square inch.

305. In the same manner as any body is pressed upon by the air, so is any given volume of the air, pressed upon at the surface of the earth, and air which would occupy a great volume, if subject to no pressure, is compressed into much smaller bulk by the superincumbent weight of air according to the amount above it. To what extent the air at the surface of the globe would expand, if relieved entirely from pressure, or to what degree of tenuity it is reduced at the top of the atmosphere, supposing its altitude to be finite, has not yet perhaps been satisfactorily demonstrated; but in the air-pump it is reduced, with facility, to a degree of tenuity not amounting to one-thousandth part of the density of ordinary air, and so regular is the diminution in the density of the air, as it is elevated above the surface of the earth, that the altitude of any locality above the surface may be estimated by examining the density of the air there, with the aid of a barosmeter.

306. The weight of a given bulk of air, its density or specific gravity, and the pressure it exerts on a given surface, or its elastic force, are all dependent on one and the same cause, viz. the mass of air contained within a given area at a fixed and definite temperature; and accordingly, tables are constructed, shewing the correspondence between the density and the pressure of the air.

307. The following illustrations will assist those who may not previously have attended to this subject, in obtaining a more precise knowledge of the weight and pressure of the air.

308. The weight of a cubic foot of air is 535.88 grains = 0.076554 lbs., and there are 13.06 cubic feet in 1 lb., and 29,260 cubic feet in 1 ton.

309. If the number of cubic feet in any given space be divided by 13.06, the quotient will be the weight of air, in that space, in lbs. Or, if the number of cubic feet be divided by 29,260, the quotient will be the number of tons.

310. The volume of 1 lb. of air is 22,570 cubic inches; therefore the volume of 14.6 lbs. is about 329,522 cubic inches, or equal to the bulk of a column having an area of 1 square inch

for its base, and a height of 329,552 inches, or 27460 feet. Consequently, the height of a column of air standing on 1 square inch, and pressing upon it with a weight of 14.6 lbs., is 27,460 feet, or rather upwards of 5 miles.

311. If London be assumed to cover a surface of 20 square miles, the weight of the superincumbent atmosphere on it amounts to 523,320,000 tons, or is equal in weight to a ball of lead of 2073 feet, or more than one-third of a mile in diameter.

312. If the diameter of the earth be assumed to be 8000 miles, its surface will be about 200,000,000 square miles, and will be pressed by the atmosphere with a weight of 5,260,000,000,000,000 tons; hence it may be calculated that the total weight of the atmosphere equals that of a ball of lead of about 317,000 feet, or nearly 60 miles in diameter.

313. In a room 12 feet square and 12 feet high, there are 1728 cubic feet of air, weighing 132.3 pounds.

314. In a room 20 feet by 15 feet and 12 feet high, there are 3600 cubic feet of air, weighing 275.6 pounds.

315. In a church 80 feet by 50 feet and 40 feet high, there are 160,000 cubic feet of air, weighing nearly 5½ tons.

316. Westminster Hall is 238 feet long, 67 feet broad, and the area of the floor is therefore 15,946 square feet. The side walls are 44 feet high, and the height to the apex of the roof is 90 feet; the cubic contents are therefore 1,068,382 feet. There are, therefore, 36½ tons of air in Westminster Hall.

317. If 20 square feet be taken as the external surface of the human body, the force with which the air presses on it is equal to 18.77 tons.

318. GASSES are pre-eminently elastic and compressible. Their elasticity is so perfect that it never is diminished by any mechanical force, though their volume may be diminished. An ordinary metallic spring may, in the course of time, lose its temper; but air never loses its elasticity or compressibility, however frequently it may have been compressed, and always acquires its original volume in full when the compressing power is withdrawn.

319. Gases, in a chemical point of view, bear the same relation to liquids and solids, into which they are considered capable of being changed by cold or pressure, though all of them have not yet been subjected to such changes, as steam bears to water and ice. The air may therefore be considered as the steam of a solid, which has been melted and subsequently converted into vapour; this vapour being produced at a boiling point so low that all ordinary temperatures at the surface of the globe are above that boiling point. Or, according to the views now generally entertained, the air may more correctly be termed a mixture of two gases, all gases being regarded as essentially similar to vapours produced by the action of heat on solids or liquids. The oxygen and nitrogen gases of which it is composed would unquestionably, so far as any opinion can be formed on this point, be condensed into liquids or solids by an extreme reduction of temperature.

320. DIFFUSION OF GASES.—Gases, like solids and liquids, are capable of an endless variety of changes, according to the combinations into which they may enter, or the decompositions which the compound gases undergo.

321. The discovery of the DIFFUSION OF GASES is one of the most unexpected and interesting results of modern science, and has shewn them to possess a peculiar property of extreme importance to the animal economy, and equally powerful in regulating the state of the atmosphere at the surface of the earth. Till it was pointed out by Dalton, whose observations have been sustained and extended by many able chemists, particularly Professor Graham, no one expected that a light gas and a heavy gas would mingle together in opposition to their natural gravities, where no chemical action ensued between them. It is now, however, satisfactorily proved, that *all gases tend to diffuse themselves through each other, even where no combination ensues*, with a rapidity varying according to the density of the gases placed in contact.

322. Light gases even descend, and heavy gases ascend, though no means of communication are afforded, except through a capil-

lary tube, and a very considerable force is exerted by the gases as they mingle.

323. In the diffusion of gases, it is found that the volume of any gas which escapes into another in a given time bears a certain ratio to its density, and each gas is therefore said to have its *diffusion volume*, a quantity proportional to the velocity with which that gas would flow into a vacuum.*

324. If any volume of two different gases be brought into communication with each other, each gas expands into a bulk equal to the sum of the two volumes, *but without any change of temperature*, and the result is a homogeneous mixture of the two gases, any portion of the mixture containing the two gases in the proportions of their original volumes.

325. The velocities with which the same gas penetrates into different gases, depends on the densities of these gases. Thus, atmospheric air diffuses itself into hydrogen more quickly than into carbonic acid gas, and hence it would appear that different gases afford, as it were, different degrees of vacuum to other gases, affecting the velocity of diffusion, but not the ultimate amount. Dalton considered that gases tend to pass or diffuse themselves through each other, in the same manner, in some respects, as they would pass into a vacuum.

326. In consequence of this power of diffusion, no gases can ever remain for any length of time at the surface of the earth, however heavy. The poisonous carbonic acid evolved by respiration, combustion, and numerous other natural operations steals insensibly into the superincumbent air, and has been detected

* The quantity is inversely proportional to the square root of its density. Thus, if certain gases were selected having the relative densities expressed by the numbers 1, 4, 9, 25, their diffusive volumes, or the volumes of each that would pass into any other gas in a given time, would be in the proportion of 1, $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{5}$; or, if one gas had four times the density of another, the denser gas would require twice the time to diffuse itself in equal volume with the rarer. If one gas had twenty-five times the density of another, it would require five times the time;—the times necessary for the diffusion of equal quantities being proportional to the square roots of the densities, and the volumes diffused in equal times being inversely proportional to the square roots of the densities.

at the greatest altitude which man has hitherto attained. All gases contain variable proportions of any gases or vapours that may have been brought into contact with them, or with any solid or liquid surface from which they may be exhaled.

327. In some circumstances, a perpetual power of exchange is maintained between different gaseous mixtures, as in the process of respiration, where, as Professor Graham has remarked, the carbonic acid in the minute air-cells in the lungs darts by a diffusive action from them into the bronchial vessels, from which it is expelled during the process of expiration. At the same moment, oxygen passes from the air that had been inspired to the minute cells. Without this process of diffusion, the noxious carbonic acid might pass and repass indefinitely in the more minute vessels of the lungs without being conveyed to the external atmosphere.

328. Again, numerous solids are sufficiently porous to permit the passage of gases by this process, and even the whole body is considered to be capable of being penetrated by gases. Hence also the extreme importance of porous clothing, which permits the diffusive action of gaseous exhalations at the surface of the body to escape with facility; whereas, when the gases exhaled from the pores of the skin stagnate around the surface of the body, their discharge by diffusion is speedily arrested.

329. Absorption or Gaseous Condensation of Gases by porous solids.—Independent of those changes that occur where gases are liquefied or solidified, by direct chemical combinations, they are capable of being condensed in large proportion by various substances, without undergoing a change of form, and of acquiring in many cases a power of action from this cause which they had not previously possessed. Thus many metals in fine powder absorb large quantities of oxygen; charcoal can absorb about 90 times its bulk of ammonia; and soils, according to their texture, also absorb this and other substances from the air which contribute essentially to the growth of vegetables.

330. It may be stated generally, therefore, that gases at the

surface of the earth are continually subject to two antagonistic powers—diffusion and absorption; the former perpetually tending to prevent the undue accumulation in a given place of any particular material, and the latter to condense it in situations to which it may be wafted by the winds, and where it may be applied advantageously, particularly through the agency of the material by which it is condensed. And as the gases condensed in this manner still retain their gaseous condition, being reduced neither to the liquid nor to the solid form, the term gaseous condensation is employed to indicate this circumstance.

331. The great tenuity of gases may be seen at once by contrasting their weight with that of equal bulks of water and platinum, the former constituting the ordinary standard of comparison, and the latter the heaviest body known.

TABLE OF WEIGHTS AND VOLUMES OF VARIOUS BODIES AT THE TEMPERATURE OF 60°. BAROMETER 30°.

NAME.	Specific Gravity.	Weight of 1 cubic inch in grains.	Volume of 1 grain in cubic inches.
Hydrogen Gas, . .	0.0689	0.021370	46.8000
Nitrogen Gas, . .	0.9785	0.303460	3.2953
Atmospheric Air, .	1.0000	0.310117	3.2246
Oxygen Gas, . .	1.1025	0.341900	2.9248
Carbonic Acid Gas,	1.5240	0.472830	2.1149
Watery Vapour,* .	0.0115	0.003566	280.0000
Water, ...	814.0800	252.460000	0.00396
Platinum, . . .	17,503.0000	5428.000000	0.000184
	Weight of 1 cubic foot in grains.	**Volume of 1 lb. in cubic feet.**	**Volume of 1 ton in cubic feet.**
Hydrogen Gas, . .	36.927	189.56	424,600.
Nitrogen Gas, . .	524.380	13.35	29,900.
Atmospheric Air, .	535.880	13.06	29,260.
Oxygen Gas, . .	590.800	11.85	26,540.
Carbonic Acid Gas,	817.050	8.57	19,190.
Watery Vapour, .	6.170	1134.00	2,540,000.
Water, ...	62.32 lbs.	27.727 cub. ins.	36.
Platinum, . . .	1340.00 ...	1.290 ...	1.67

* Thin and attenuated vapour, such as exists at the temperature of 60°.

CHAPTER V.

EXPLANATORY NOTES ON ATMOSPHERIC AIR.

332. THE history of ventilation throughout the whole of this work, consisting essentially of an enquiry into the action of the air upon the human frame, and the means by which its due influence may be effectually sustained, the remarks on air, in this chapter, are confined to some brief notes on the more prominent circumstances connected with this subject, with which the reader should render himself familiar.

333. The atmosphere being the great aerial ocean into which all gases, vapours, and bodies held in solution or suspension by them, ultimately pass, its precise composition is necessarily extremely complicated and very various in some respects, according to the locality in which it may be examined, and the state of the weather at the moment. The emanations produced by local causes, however powerful in their influence, form an amount so exceedingly minute, compared with the mass of the atmosphere, except in very peculiar situations, that their proportion, and in numerous cases their nature, has not been ascertained. In particular places, where impurities are evolved, they may be in some cases so concentrated as to constitute the greater, if not the whole of the specimen examined, and the amount of carbonic acid conveyed to the atmosphere in a given time, and removed again, may be considerable, comparatively speaking; still, however, the amount of impurity in atmospheric air, forms in general but a minute per-centage of the

mass, the carbonic acid, which exceeds largely all other impurities, varying on an average from three to six parts in ten thousand.—(Saussure).

334. Weight of Air.—According to the elaborate experiments of Dr Prout, 100 cubic inches of atmospheric air, deprived of watery vapour and carbonic acid, weigh 31.0117 grs.

335. Density of Air at different altitudes.—The air is found to be less and less dense as it is examined at greater and greater altitudes. A cubic foot of air at the surface of the sea expands to two cubic feet at an altitude under three miles, and to four cubic feet at an altitude under five and a-half miles, so that air may be said to have one-half and one-quarter its density at the surface of the sea, when conveyed to these respective altitudes. The diminution of density proceeds progressively with the altitude. Were air equally dense at all altitudes, its pressure at the surface of the globe indicates that its height would then be nearly five and a quarter miles. But from the progressive diminution of density at each successive altitude, its height is very much greater. A height of forty-five miles has been supposed to form the extreme limit of the atmosphere of the earth; but, according to other views, the air extends to an infinitely greater altitude, but of an extreme tenuity, which it is difficult, if not impossible, at first to appreciate distinctly, though it may be expressed by figures.

336. Winds and Currents.—Every cause that alters the density of the air, disturbs the equilibrium of the atmosphere, and draughts or currents immediately ensue, these being the natural sequence of the local action of heat, or of any mechanical impulse communicated to the air. For, if the air be in equilibrio, and any portion be expended by heat, it no longer resists the denser atmosphere around it, and currents set in upon it in every direction, and press it upwards. If, however, it be condensed by cold, it then presses outwards on every side; the course of the currents is reversed. The great aerial currents that 'culate between the poles and the equator, the trade winds,

the sea and land breeze, and the local currents that are observed in every district where they are modified by peculiar causes, owe their origin in general to variations of density dependent on variations of temperature. Electricity and other causes may produce wind or fluctuations in aerial currents, but no cause so generally effects movements of the air, whether in the great phenomena of nature, the processes of art, or in the habitations of men, as changes of density dependent on alterations of temperature. When one current meets another, eddies are produced such as may be constantly observed in places where varied deflections or rotatory movements are given to different portions of air. In hurricanes, these rotatory movements have been observed extending over a space many hundred miles in diameter.

337. TEMPERATURE OF THE AIR.—The range of variation of temperature which has been recorded at the surface of the globe, exceeds 180 degrees. The average temperature at the pole has been supposed to be —13°, and a temperature as high as 130° in the shade has been mentioned as having been observed in equatorial regions.

338. The rays of the sun appear to have little or no direct effect upon atmospheric air unmixed with mists and vapours, or suspended impurities. They heat the surface of the ground, which then conveys the warmth to it. In clear nights, on the other hand, the ground loses heat by radiation, and the air in contact with it becomes cold.

339. The temperature of the atmosphere, which is always greatest at the surface of the earth during sunshine, but not in clear nights when the radiation is great, diminishes progressively as the air recedes from the surface of the earth. At the polar regions, the temperature is so low at the surface, that perpetual frost and snow are observed there, and as the equator is approached, the line at which ice or snow is always observed becomes higher and higher, being 15,000 feet above the level of the surface at the equator itself.

340. Though the temperature of the air be low at great altitudes from the expansion of the air, there is as much absolute heat in a given weight of cold attenuated and expanded air, as in the same air when at a higher temperature in lower regions of the atmosphere, where its particles are more closely approximated to each other.

341. MOISTURE.—The moistnre in the air is not to be regarded as an adventitious ingredient, but rather as an essential component of atmospheric air. Its amount varies not only in different places, but in the same place at different times. Air feels moist more or less, though the same amount of moisture be present, according to its temperature. It is not, accordingly, the quantity of moisture alone that must be looked to, but rather the tendency of the air to retain the moisture in solution, or to deposit it, which is necessarily dependent both on the temperature and quantity of moisture. In summer, in this country, when the air is warm, there is much more moisture in the air than in winter, but it does not feel so damp, as the tendency to deposition is less than in winter.

342. The importance of studying the state of the atmosphere in respect to moisture, in connection with the history of ventilation, will become at once apparent from the fact, that the larger the quantity of moisture in the air, the larger the amount of air required for the evaporation of that moisture from the body which constitutes the insensible transpiration, and the greater the difficulty presented to the lungs and skin in casting off the products that are always discharged from them. The *treacly atmosphere*, as it has been so emphatically termed in some warm climates, is a warm atmosphere loaded with moisture, and therefore resisting evaporation from the body; it is an atmosphere more prone to deposit its moisture upon the body, than to relieve it by evaporation, and, accordingly, moisture exhaled from the body becomes very marked in the form of sensible perspiration.

343. Moisture requires, in general, to be added to air in cold climates, in winter, in proportion to the temperature communi-

cated to it before it approaches the person. If cold air be heated in spring and summer by natural causes, it absorbs a proportional share of moisture in general from the surface of moist ground, lakes, and rivers, or from the ocean, and thus reaches the system in a congenial condition. On the other hand, if cold and dry air be heated artificially without receiving moisture, its increased power of absorbing moisture renders it offensive to the system.

344. Again, in cold climates, large quantities of moisture are constantly removed from the air by condensation, carrying along with them a proportion of carbonic acid and other impurities. This deposition leaves the residual air much more pure than it otherwise would be. In all expeditions to the Polar Regions, as in Captain Sir Edward Parry's voyage, this deposition has always been noticed to take place to a great extent.

345. The following paragraphs on this point, and the table in the Appendix, explain the more important facts that demand attention, in respect to the communication of moisture to the air, and its deposition from it.

346. When the vapour of any body is removed from contact with the liquid from which it has been generated, it possesses the properties, and is subject to the laws, which are common to all gases; it is perfectly elastic and compressible, and it is capable of expansion by the increase of temperature, and contraction by its diminution, according to the rule which all gases follow, namely, it expands 1-480th part of its bulk at 32°, for every additional degree of temperature to which it may be subjected, and contracts similarly when the temperature is diminished, provided that the diminution does not extend beyond the point at which it has been generated, in which case it is necessarily liquefied.

347. The quantity of vapour which can be generated from a liquid depends upon the space which it is permitted to fill, and the temperature to which it is exposed. The amount of evaporation is not affected by the presence of the air or of any other

aeriform body, for as much vapour is found in a space filled with the densest gas, as in a vacuum of equal extent. The presence of another gas affects only the rapidity of evaporation, and produces no change in the ultimate amount. According to Rudberg's experiments, the dilation of gases by heat amounts to 1—493 feet for every degree of Fahrenheit's thermometer.

348. The temperatures being equal, the quantity evaporated is proportional to the space into which the vapour is permitted to ascend. Thus, a vessel having the capacity of 10 cubic feet contains ten times the weight of vapour which one of 1 cubic foot can contain at the same temperature. If a vessel, therefore, be increased or diminished in cubical contents, and be at the same time freely supplied with water, a corresponding increase or diminution will take place in the quantity of vapour which it contains. The quantity is increased by a farther amount of evaporation from the generating liquid, and its diminution is effected by a deposition in the liquid form of part of the vapour previously existing. Since the amount of evaporation is totally independent of the presence of another fluid, a given volume of air can contain the same weight of vapour as a vacuous space of the same dimensions, and the greater the volume of air to which an evaporating surface is exposed, the greater is the quantity that ascends in the form of vapour. It is on this principle that a current of air or wind is favourable to evaporation, for the successive volumes, thus passing over the liquid, receive each their due amount of vapour, and prevent the stagnation of air already saturated.

349. As vapour possesses a certain elasticity or pressing force, when existing in a space free from the presence of any other gas, so, when it rises into a space already filled with gas, it adds its elasticity to that of the gas, and the elasticity of the mixture is then expressed by the sum of the elasticities of the gas and the vapour. The result of such an increase in elasticity is an expansion in volume, in an equal proportion. The elasticity of the vapour of water at 80^{0} Fahr., has been found to be capable of supporting a column of mercury 1 inch high. If,

therefore, a vessel containing dry air of ordinary pressure (30 inches of mercury), and at the temperature of 80°, receive its due amount of watery vapour, the elasticity of the mixture becomes equivalent to the pressure of 31 inches of the barometric column; and if the vessel permits the extension of volume, the mixture will expand until it attain the same pressure as that of the surrounding atmosphere. 100 cubic inches of dry air at 80°, would thus expand to 103⅓ cubic inches on being saturated with moisture.

350. The amount of evaporation into equal spaces is dependent upon the temperature, and increases considerably on a small increase of heat. Between 32° and 100°, the amount of evaporation is doubled by the addition of about 20°; or at 52°, it is double that at 32°. It necessarily follows from an increased amount of evaporation into a given space, that the density of the vapour must be greater, the greater the temperature at which it exists. It has been found, for example, that the vapour of water at 32°, has about 1-300th part of the density of air; at 212°, it has nearly half; and at 350°, it is about four times as dense as air: its limit of density being 815 times that of air, or equal to that of the water generating it. The amount of elasticity is in exact proportion with the density, while the volume occupied by a given weight of vapour is less, according as the density and elasticity are greater, and greater according as they are less.

351. The effect of temperature upon the amount of evaporation gives rise to many phenomena connected with the state of the atmosphere in regard to moisture, rain, dew, &c. A volume of air is said to be saturated with moisture, when it contains the amount of vapour of the density and elasticity due to its temperature. If it contain less than its due proportion, it is ready to absorb an additional quantity from any water or moist surface with which it may come in contact; it cannot contain more; it deposits any surplus in the vesicular form, or as dew or rain. By increasing the temperature of a given volume of air, its capacity for moisture is increased; and by cooling it is diminished. When

a glass vessel containing air saturated with vapour is cooled, the moisture is seen deposited upon the sides of the vessel; and when it is again heated, the moisture disappears and becomes insensibly diffused through the warmer air.

352. When the walls of a crowded apartment run down with moisture, this indicates that the air in contact with them is saturated with moisture, and that they are colder than the air. If they were not, there would be no deposition.

Again, when a warm south-west wind succeeds a long and severe frost, the same effect is observed. The water that appears does not exude from the walls; it is deposited from the warm air, when its power of solution is diminished by coming in contact with the cold wall.

353. When air, saturated with moisture, shall have been heated without being permitted to absorb a farther quantity of vapour, it expands according to the usual law of gases, and it may be again cooled without any deposition of moisture, until it reaches the degree of temperature at which the quantity of vapour which it contains can exist. This degree of temperature is called the dew-point, because any farther reduction causes a deposit of moisture in the form of dew.

354. A quantity of air, again, may contain a large amount of moisture in the vesicular form, such as a cloud or fog, when it becomes visible and opaque, and which may be rendered transparent and invisible, by its being converted into vapour on the addition of heat. It was found, for instance, that, in some experiments made in London, the densely foggy air, which attracted attention at that time, was rendered clear and cloudless on being heated to 80°, indicating that about 1-70th part, by weight, of that air, was water.

355. In tables expressing the elasticities of watery vapour at various temperatures, the numbers are usually taken from the results of experiments made by Dalton on this subject. The columns of specific gravities, and weight of a cubic foot, are calculated from the numbers expressing the elasticities, and that

containing the weight of vapour, diffused through a cubic foot of air, is formed from a combination of the numbers expressing the weight and the elasticity in the following manner :—

356. A cubic foot of perfectly dry air of an elasticity equivalent to 30 inches of mercury, on becoming saturated with moisture, attains an elasticity equal to the sum of its own elastic force, and that of the vapour. If the temperature, for instance, be 80°, it attains an elasticity of 31 inches of merc., and tends to expand until it becomes $\frac{31}{30}$ of a cubic foot, having at that increased volume the same elasticity (30 inches) as before saturation. The quantity of moisture due to 1 cubic foot is accordingly diffused through $\frac{31}{30}$ of a cubic foot, and the quantity remaining in the space of 1 cubic foot after such expansion, is therefore $\frac{30}{31}$ of the quantity contained in the cubic foot before expansion, that is $\frac{30}{31}$ of the weight of 1 cubic foot of watery vapour at 80°. In the same manner, all the numbers expressing the weight of moisture in a cubic foot of air at a given temperature, are to be found by dividing 30 times the weight of 1 cubic foot by the sum of 30, and the elasticity corresponding to the temperature.

357. ELECTRICITY OF THE ATMOSPHERE.—The intimate connection that subsists between the electric power, and all bodies at the surface of the globe, necessarily renders the history of atmospheric electricity an object of great interest in connection with the changes of which atmospheric air is susceptible. Hitherto, however, the investigations have not yet been carried sufficiently far to admit of any practical applications being made with that certainty and precision which has obtained in respect to temperature, except in so far as the protection of the lightning rod has afforded such comparative security from the influence of the thunder-storm, both at sea and on shore. As it cannot be doubted, however, that every movement and every chemical action, both in the animal and vegetable system, and in the inorganic world, is accompanied with electric changes, many new results bearing on the animal eco-

nomy may still be anticipated with the progress of discovery in electricity, such as have been recently applied in the arts and manufactures.

358. That changes in the electric condition of the atmosphere produce very marked changes on the constitution and feelings, has long been universally admitted, but it is only recently that any attempts have been made to enter precisely on this question. The following extracts from a series of communications to Mr Walker's Journal of Electricity, by Mr Weeks, shews the manner in which observations have begun to be recorded in reference to the electric state of the atmosphere; the extension of such observations cannot fail ultimately to lead to important practical results. If we merely recollect the important fact, that, according to its electric condition, the body may become a centre of attraction or repulsion to all the atmospheric and other particles with which it may be surrounded, we cannot fail to assent to the proposition, that much may be expected from the farther prosecution of such inquiries, though the difficulties of the investigation, arising from the complexity of the subject, must lead the inferences announced at first to be received with caution.

From the Transactions of the London Electrical Society for 1841.

Day of month.	Time in hours and minutes.	Thermometer.	Barometer in inches and hundredths.	Wind, its direction and character.	Weather and modifications of clouds.	Electrical condition of atmosphere.	General Remarks.
10	...	60	29.40	Light breezes, variable from N. to W.	Thickly clouded at great altitudes.	Neutral.	Scarlatina in a mild form somewhat prevalent.
11	...	58	29.40	Cold breeze N.	Gloomy, overcast sky.	Neutral.	
12	...	60	29.56	Very slight N. by E.	Hazy upward, with little fine rain at times.	Neutral.	Cynanche tonsillaris frequent among children and young persons.
19	2 P.M.	66	29.32	Light breezes W.	Thunder from clouds distant about a mile.	Negative.	Waves of electric fluid rush through the apparatus subsequent to each successive lightning flash.
...	2.20 P.M.	...	...	...	Rain in abundance.	Positive.	Currents of small sparks.
		...	...	...	Frequent showers.	...	No further trace of electric action.
20	...	64	29.50	Strong at times, W.SW.	Densely clouded.	Neutral.	
...	5 P.M.	...	...	Decreased.	Continued gentle rain.	Neutral.	Numerous cases of odontalgia.
21	...	66	29.60	Sudden squalls from W.SW.	Occasional gentle showers.	Neutral.	
...	6 P.M.	...	...	Moderate.	Clear sky.	Neutral.	Sensation of languor, and muscular relaxation very general.
22	...	66	29.65	Mere zephyrs, W.SW.	Clouds and thin haze beneath.	Neutral.	
...	1.25 P.M.	...	...	Increased to smart breeze, SW. by W.	Hasty dispersion of clouds, except fine cirrose fibres here and there.	Positive.	Slight divergence of electroscope immediately on dispersion of clouds, increasing for one hour, becoming uniform, and ceasing at sunset.
23	...	64	29.50	None.	Blue sky and modifications of cirrus alternately.	Neutral.	Odontalgia, rheumatism, and various neuralgic affections abound.
24	...	...	...	None.	Clear blue sky.	Neutral.	
...	2 P.M.	66	29.40	Smart breeze has just sprung up from SE. by E.			
...	6 P.M.	...	...	Has ceased.	Clouds increased — continued rain by night.	...	The most delicate test instruments fail to detect any free electricity. All the last named diseases are increased; extreme languor of the animal system prevails.

359. Excluding moisture and carbonic acid, which are noticed elsewhere, atmospheric air consists essentially of oxygen, mixed with four times its bulk of nitrogen (21 of oxygen and 79 of nitrogen are more commonly mentioned). This amounts, by weight (omitting fractions), nearly to 23 of oxygen and 77 of nitrogen. These gases do not condense, nor do they present any marked chemical changes when mingled in the proportions mentioned. They resemble a mixture of the two gases, rather than a chemical combination. They do not separate, notwithstanding their different specific gravities, according to the law of the diffusion of gases already explained, and the proportions in which they are associated are not incompatible with the notion that they may be approximated, if not actually combined, by a feeble chemical attraction.

360. The elements of air can unite in several different proportions besides those observed in atmospheric air, constituting a very marked and interesting series of chemical combinations, as explained in the following table. Supposing air to consist of two particles of nitrogen and one of oxygen, a supposition not exactly in accordance with modern analysis, though the proportions, so far as they differ from what might be explained in unison with this view, according to the laws of the proportions of combination, are not so distant from the proper theoretical numbers as to preclude the supposition that any difficulty on this ground may yet be reconciled by more precise analysis.

	Nitrogen.	Oxygen.
Atmospheric air,...............	2 particles.	1 particle.
Oxide of nitrogen, ...	1 ...	1 ...
Binoxide of nitrogen, ...	1 ...	2 ...
Hyponitrous acid,...............	1 ...	3 ...
Nitrous acid,.....................	1 ...	4 ...
Nitric acid, ...	1 ...	5 ...

361. Oxide of nitrogen is the intoxicating gas whose very singular properties were discovered by Sir H. Davy. The other compounds of oxygen and nitrogen are fatal to animal life. All the above compounds are mutually convertible according to

various chemical arrangement, any redundant proportion of either element being separated. Rain-water often affords traces of nitric acid, which is produced more particularly during thunder-storms, by the action of electricity in the air.

362. OXYGEN is the great element whose power on the material world is more marked than that of any other substance. Its tendency is to sustain a slow combustion with all varieties of animal and vegetable matter. These are composed of oxygen, hydrogen, carbon, and nitrogen, the latter being comparatively rare in the vegetable kingdom. When its action is fully developed, it produces

Carbonic acid with carbon,
Water with hydrogen, and
Nitric acid with nitrogen.

363. In the mineral kingdom, its oxygenating or oxidating* influence is always in operation, though not in so marked a manner. Thus, in the oxidation of iron, it promotes the disintegration of rocks, and there are few substances at the surface of the globe with which it is not already largely associated, or on which it does not tend to act. In the vegetable and animal kingdoms, the great tendency is to produce combinations whose amount of oxygen is small compared with what is observed in the mineral kingdom, and when these decay, the products, when not oxygenated, or only in a low state of oxidation, may tend to produce disease; but when highly oxidated, carbonic acid, water, and nitric acid are formed, and these substances have no tendency to form any of those putrefactive or peculiar combinations, such as are prone to induce fermentation or disease, according to the circumstances under which they are applied. Oxygen, accordingly, as it affects the system, may be considered as producing a slow fire, whose regulated and tempered action produces a mild and genial warmth, by the oxidation induced through respiration. When oxygenation is imperfect from excess of food, defective respiration, or other causes, the system is generally overburdened

* Terms employed to indicate the combination of different bodies with oxygen.

with fat, or its power and tone extremely reduced by loss of appetite, more especially where the supply of air is indifferent. When there is a deficiency of food, it preys upon the body itself, its operation in cases of starvation consisting literally in destroying its substance by the chemical changes induced, which tend to resolve its carbon and hydrogen into carbonic acid and water.

364. NITROGEN, the other element of air, has not yet perhaps been traced so successfully in all its varied influence upon the animal economy as oxygen. It has been considered to act principally by diluting and tempering the too powerful action of the oxygen that might otherwise ensue. But its almost universal presence in the products formed by animal life, its power of penetrating the system in the same manner as other gases, and the fact that it is absorbed or exhaled under different circumstances, lead certainly to the belief, that its function is much more important than it was at one time supposed to be.

365. The CARBONIC ACID in air is not to be regarded in the light of an impurity, when its amount does not exceed one part in two thousand, as it serves the important purpose of presenting carbon to the vegetable kingdom, without proving injurious to the animal frame. See Respiration—Vitiated Air—Combustion—Fires—and Coal-Gas, for farther observations on Carbonic Acid.

366. It appears from the most recent experiments, that there is no reason to suspect that any deterioration ensues from year to year in the constitution of the atmosphere. Extensive operations take place at the surface of the globe, by which its oxygen is restored in the same proportion in which it is consumed by the processes of combustion, respiration, and other natural operations. The two kingdoms of animated nature are more peculiarly instrumental in sustaining the due balance of oxygen, vegetables under the influence of the sun replacing generally the oxygen consumed by animals, and absorbing the carbonic acid which they expire. It is sufficient here to state, that the very rigid and accurate analysis of atmospheric air, made by Humboldt and Gay Lussac about 40 years ago, corresponds in its re-

sults with the elaborate and able researches of MM. Dumas and Boussingault, recorded in the Annales de Chimie et de Physique for November 1841, and these, again, coincide also with researches made at the same time, both at Berne and at Faulhorn, by M. Bremner.

367. But though the probability may be great that the air undergoes, under present circumstances, no permanent change, it is not improbable that various zones or districts may, from their vegetation or other causes, have, at times, an increase or diminution in the per-centage of oxygen or carbonic acid, in the same manner as local impurities may be detected in innumerable situations, and be traced to the action of special causes. Dr Dalton, in particular, has recorded some observations, where, if the different amounts of oxygen indicated were not within the limits of the unavoidable errors of experimenting, a difference in the per-centage of oxygen must have existed. In the vicinity of rich and luxuriant foliage, unaccompanied by decomposing vegetable matter, the action of the plants in the sunshine must necessarily tend to produce a highly oxygenated atmosphere. Saussure has indeed shewn, that in such situations the amount of carbonic acid in the air is less during the sunshine than in higher regions.

368. Again, the extreme activity of volcanoes in different parts of the globe may communicate occasionally special products to the air, and the possibility of planetary influence ought not to be entirely overlooked. The former by the direct communication of gaseous impurities, and the latter by the induction of peculiar electro-magnetic or other conditions, may affect the action of the atmosphere on the human frame. That even the planets do exert some important physical influence on the living frame from time to time, has been rendered probable by varied observations as to the state of the weather at particular conjunctions; nothing, however, but the most extended and repeated observations can give confidence in such conclusions. But in the same manner as the light they emit reaches the eye by which they are recognised, so also it is evident that they must exert some in-

fluence upon this planet, however trifling comparatively that may be.

369. In attending to the influence of air upon the human frame, the memoranda subjoined should not be forgotten, particularly in studying the circumstances that modify the amount of air required in a given time.

370. 1. WARM AND COLD AIR.—In the great majority of cases, the temperature of the external atmosphere is below that of the human frame, even when it feels warm, and, consequently, exerts a cooling power as it comes in contact with it, the effect being proportional to the amount that passes in a given time; unless heated above 98°, it does not directly warm the system, though it feels warmer and warmer as its temperature approaches this point, in consequence of exerting a less and less cooling influence, such as in ordinary temperatures we are always though unconsciously accustomed to.

371. 2. MORNING AND EVENING AIR.—Morning air is in general much more pure and refreshing than evening air, having deposited much dew during the preceding night, when the temperature is low and the air clear. The proverbial purity and salubrity of the morning air arises essentially from this cause. Its comparative coolness also modifies its effects.

372. 3. NOON AND MIDNIGHT AIR.—Air during the day is always receiving accessions of moisture and volatile impurities from the surface of the ground. On the other hand, air, during the night, is constantly depositing, in mist and dew, impurities that may be associated with the moisture evaporated throughout the preceding day.

373. 4. AIR OF THE OCEAN AND OF THE DRY LAND.—Air on the ocean may be considered saturated with moisture, and associated with a little saline matter. Air, on the dry land, is not only apt to be contaminated with impurities, but is often deprived of part of the moisture it may previously have had by the absorptive powers of the soil.

374. 5. SUMMER AND WINTER AIR.—Air, in summer, may feel more dry than air in winter, and still contain more mois-

ture, as its higher temperature gives it a greater dissolving power than is observed in cold air.

375. 6. SPRING AND AUTUMN AIR.—In spring and summer, active vegetation tends to increase the amount of oxygen in air. In autumn, the presence of impurities prone to putrefaction render the air less wholesome.

376. 7. HIGH AND LOW AIR.—Air, at a great altitude, is generally much more pure than air at the surface of the ground, if any local source of impurity be avoided; it is also colder in the sunshine and warmer at night in clear weather than air at the surface.

377. 8. AIR ON DRAINED AND UNDRAINED LAND.—Air resting on land imperfectly drained, is much less pure in general than on ground well drained. Thus, in level districts, impurities on a clay soil are very seldom entirely removed; but if the soil be porous, as where gravel abounds, the impurities conveyed to it are quickly absorbed.

378. 9. AIR OF THE MOUNTAIN AND OF THE VALLEY.—In the same manner, the air of the mountain, which is incessantly renewed from the freedom of the currents in such districts, is not only comparatively pure from this cause, but the facility with which all decaying debris are oxidated, tends to give a still higher degree of purity. In the valley, the reverse is necessarily the case.

379. 10. AIR IN THE SUNSHINE AND IN THE SHADE.—In the sunshine, the whole system is powerfully stimulated by the rays that play upon it; the air, at the surface of the ground, is warmed and universally agitated by the intermixture of ascending and descending currents that consequently ensue; the process of oxidation and evaporation is much accelerated, and the tendency of matters in solution to be deposited is greatly diminished. In the shade, the temperature is lower from the absence of the direct influence of the sun's rays; the loss by unrequited radiation from the surface of the earth, when the sky is clear, renders the surface of the ground still colder, and instead

of that living agitation which is observed in the sunshine, the air tends to remain comparatively stagnant and cold below, or horizontal currents of low altitude are determined, loaded with dew or other condensed impurities. In a clouded atmosphere, all these effects are greatly or almost entirely prevented, thick clouds preventing as much unrequited radiation in the shade, or at night, as they intercept the rays of the sun by day. The comparative quiescence of air at night is one cause of the great distinctness of sound that is then observed. In many places where fires are sustained all night, the smoke may often be observed quiescent before sunrise, and in the form of a cloud, at an altitude of a few hundred feet, having been accumulating for many hours previously. In the day-time this is rarely observed, and never to the same extent as at night.

380. The first effect of the rays of the sun in the morning is to produce considerable evaporation from the surface of the land or of water, and, when the superincumbent air is cold, the condensation of this moisture produces a mist.

381. 11. Town and Country air differ in purity, temperature, and in protection from draughts and currents. The warmth of town in winter is favourable to health; but any advantage from this cause is, in some towns or special districts, more than counterbalanced by the influence of the various noxious products communicated to the air in cities. This subject is so important, that a separate section is devoted to the consideration of impurities in air. In the country, a house situated at a moderate elevation, equally free from the severity of the mountain blast and the stagnation of the valley, not encumbered by trees, nor yet distant from vigorous vegetation on well drained land, and, above all, so located as to receive the greatest possible amount of the sun's rays in the individual apartments by the arrangement of the windows, a due regard being paid to protection from cold, may be considered as placed in the most favourable circumstances for the promotion of health.

382. 12. Dry and Moist Air are exceedingly different in

their effects upon different constitutions, the former absorbing and the latter communicating moisture to the body. See the preceding paragraphs on Moisture.

383. 13. NORTH and EAST WIND—SOUTH and WEST WIND.—Winds from particular districts necessarily acquire peculiar qualities from the places over which they pass; and as examples are familiarly known, where even palpable dust and ashes have been carried for many hundreds of miles, so also peculiar temperatures, emanations, malarious impurities, and deleterious gases and vapours, may be conveyed to a still greater distance, in proportion to their subtlety and the volatility of the material communicated. Nor is it unreasonable to suppose, that the friction of one portion of air upon another, or upon the earth, and other causes, may tend to induce some peculiar magnetic quality. But no distinctions are so familiarly known as those of the north and the east wind, as contrasted with the south or the west wind in this country. The former are essentially cold and dry in general, when compared with the latter; and accordingly, by the free addition of steam, and a proper elevation of temperature, an easterly wind, as it enters any house, may be made to approximate in character to the south-west wind.

384. There are other varieties of atmosphere dependent on the electric condition of the air, the presence of dust and other volcanic products, peculiar natural emanations from the soil, or products formed artificially in extensive operations of art, but the more important of those that require attention in this work, will be noticed in other chapters. (See Smoke and Vitiated Air.)

CHAPTER VI.

BRIEF REMARKS ON THE NATURE OF RESPIRATION.

385. Respiration consists in the alternate inspiration and expiration of air. It may be termed, in the language of Harvey, the "ventilation of the blood," the object being to remove vitiated air which is exhaled in the lungs, and to supply a corresponding quantity of fresh air. By this process, the blood is purified, and, according to the opinion now generally entertained, the inspired air gives its oxygen directly to the blood in the lungs, from which it passes to the heart, and is thence transmitted by the arteries to every part of the living frame. In the lungs, the oxygen absorbed by the blood is considered to react more especially on the red particles, giving them a florid tint, and, in the extreme branches, or capillary extremities of the arteries, carbonic acid gas is developed, this change being accompanied with the production of that temperature which is so wonderfully sustained in the living system, and with other changes necessarily associated with the nutrition that the blood conveys to each individual part of the body, before it returns by the veins to the heart, and commences again the same series of changes. The colour of the blood in the veins appears of a dark purple tint.

386. Respiration, accordingly, is a function of the utmost importance to the animal economy, and one which cannot be interrupted beyond one or two minutes in man without death ensuing, unless in cases of suspended animation, accompanied by fainting. The movement of the air in respiration is commenced by a series of muscular actions in the intercostal muscles, and in the diaphragm which separates the chest from the abdomen. By

these the cavity of the chest is enlarged, and air is forced in at the mouth and nostrils, through the windpipe, into the cells of the lungs, distending them so as to fill the increased area of this cavity. Expiration is produced principally by the elasticity of the lungs which contract to their former dimensions and expel a portion of air, the relaxation of the intercostal muscles and of the diaphragm facilitating this movement.

387. The force of the heart, and other causes, determine the circulation of the blood. The blood conveys equally nutrition from the food, and oxygen from the air, to the whole frame. It is justly termed a vital fluid, not only from the functions it performs, but also from many peculiar properties which it presents, and from the organic structure of the red particles which it usually presents. It undergoes incessant changes throughout the whole period of life, continually receiving additions from the digestive organs, and from every part of the body, through a system of vessels that pervade the whole frame, and are commonly termed the absorbent vessels, as well as from the external atmosphere. It is also constantly depositing new matter in every part of the living frame, another system of vessels elaborating all the peculiar tissues or component parts of the living body; while a third series of changes are dependent on the materials expelled through the medium of the lungs or other organs. Though, then, the changes effected during respiration consist essentially in the evolution of carbonic acid and the absorption of oxygen, they may be modified in endless variety by the following circumstances:—

1. The condition of the blood, as dependent on health, diet, and habit, in individual constitutions.

2. The purity of the air supplied.

3. The temperature of the air.

4. The moisture in the air.

5. Peculiar impurities in the air.

6. The quantity of air respired.

7. The facility with which the inspired air gains access to the blood.

8. The tone and condition of the respiratory organs.
9. The condition of the skin.

388. All these circumstances affect powerfully the nature of the respiratory changes in each individual case. The blood may be too much, or not sufficiently oxygenated. Volatile impurities may be exhaled or absorbed. The respiratory movements may be excessive or deficient. The respiratory tubes may be clear or obstructed, and numerous minor changes may be determined or influenced by exercise, rest, excitement, or any of that endless variety of circumstances that affect the human frame.

389. The blood, then, is subject to incessant varieties in its precise chemical constitution. A free atmosphere well supplied, oxygenates and destroys numerous impurities that tend otherwise to lurk in the system, and develope disease. Powerful deoxidating compounds, if volatile, generally produce extreme depression (where they do not cause local irritation), as prussic acid and hydrosulphate of ammonia. Bodies abounding in a great excess of oxygen tend to act in an opposite manner, and produce direct destruction (corrosion or decomposition) of the living tissues, by excessive oxidation.

390. In the same manner, numerous minor effects are often produced by the state of the atmosphere developing peculiar chemical changes, which may influence powerfully the health and feelings, though modern chemistry may still fail frequently in detecting their precise action.

391. The respiration of invalids is often exceedingly affected, not only in the quantity, but also in the quality of the materials exhaled. The lungs often discharge large quantities of offensive volatile products from the system. The amount of carbonic acid exhaled is also very considerably increased in some cases, and hence a much larger supply of air is then required than under other circumstances.

392. Some products received into the stomach may be exhaled in part from the lungs without change, as spirit of wine,

which, when taken freely, escapes in part unchanged, both from the surface of the lungs and from the surface of the skin, from which it has been condensed and shewn in a pure form. Hence the familiar fact, that individuals in a small and crowded apartment, and not partaking of the spirituous liquors that the majority are indulging in, are still affected by them from the amount of alcoholic vapour that floats, in such cases, in the atmosphere of a badly ventilated apartment.

393. One of the most important circumstances connected with the history of respiration, is the great extent of the surface of the lungs, and hence its extreme power when employed as a medium of affecting the whole frame by the action o volatile therapeutic agents. The lowest estimate I have met with gives fifteen square feet as the area of surface of the cells of the lungs. Dr Monro has estimated the area at about 400 feet. The highest estimate given is 1500 feet. Results so widely different indicate the necessity of estimates on this point being much more precisely entered into than hitherto, before much confidence can be attached to them. So far as I have been able to ascertain the opinion of anatomists, 400 feet of surface does not appear an excessive estimate, but none whom I have met had themselves entered practically into this question.

394. The developement of animal heat is considered one of the great objects of respiration, the carbonic acid exhaled from the lungs being formed by a species of slow combustion by the oxygenating influence of the absorbed oxygen.

395. A reference to illustrations in Part I. on respiration and transpiration, and particularly to the table on respiration, will assist the reader in tracing some of the more important facts connected with respiration, and examining its bearing on ventilation. He should remember, however, that the amount of air required for ventilation is greatly modified by many circumstances, independent of respiration (See Chap. VIII.); and that, in ordinary respiration, only a small portion of the air in the lungs is changed, varying from a tenth to a fifteenth part. Many individuals, by a very forced effort, and loading the lungs

previously by a full inspiration, can expel from 100 to 200 cubic inches of air. The lungs of some individuals appear to be capable of containing, during life, about 300 cubic inches of air.

396. The manner in which the inspired air conveys oxygen to the blood, and receives carbonic acid in return, is exceedingly curious. The air inspired, and occupying, perhaps, only the branches of the trachea, by a process of diffusion (see the diffusion of gases), discharges oxygen into the air-cells of the lungs, being replaced by carbonic acid, which leaves these cells. A similar movement then ensues between the oxygen in the cells, and the carbonic acid in the blood,—the fine membrane that lines the cells in the lungs being no barrier to this movement.

397. Respiration is considerably affected by the state of the skin, and the activity of the function of transpiration. The surface of the skin has the power, like the surface of the lungs, of absorption and exhalation. The skin in different individuals is very various in these respects; cases are known where scarcely any cutaneous exhalation can be traced, and in these the exhalation from the lungs is excessive. Where the functions of the skin have been suppressed, the lungs generally suffer from an increased action, which is relieved when the functions of the skin are restored.

398. The skin evolves carbonic acid gas, and moisture, charged with animal matter, in minute quantity. The precise manner in which the carbonic acid so evolved is produced, has not hitherto been determined.

399. When the moisture is exhaled in a dry atmosphere, or in air capable of dissolving it as fast as it is exhaled, the perspiration becomes insensible. But when the air cannot dissolve all the moisture, then the perspiration becomes sensible, a portion appearing in the liquid form.

When the body is exposed to great heat or exercise, and the exhalation is removed readily by the surrounding air, one, two, or more pounds of moisture may be discharged in a few hours.

But when the system is attenuated by long fasting, and deprivation of liquids, and the atmosphere loaded with moisture, a large portion of water is absorbed, which adds in a marked manner to the weight of the body. In some cases of disease, the power of the skin in absorbing moisture is greatly increased.

400. The true skin is covered with the elastic cuticle, which is retentive of moisture, under peculiar circumstances. The precise manner in which moisture proceeds through it is not known. The number of pores or apertures in the true skin is said to be 7200 on a square inch.

(For farther information as to the amount of carbonic acid and moisture exhaled by respiration and transpiration, see Part I.)

CHAPTER VII.

AMOUNT OF AIR REQUIRED FOR VENTILATION.

401. In all questions connected with ventilation, it may be proper to remark, that the standard of health may be generally considered inferior to that which is desirable and attainable. We ought not merely to look to the supply which the constitution can bear or tolerate, but that amount which will sustain the highest state of health for the greatest length of time.

402. No question is more important than that which forms the subject of the present chapter. In ventilation, the amount of supply is the first thing to be determined. I have no hesitation in stating, that, though an endless variety of adjustments have been made under the varied circumstances in which I have had to introduce systematic ventilation, no question engaged so much time, nor was any other point the result of such continued investigation, as the amount of air to be supplied. It became imperative to enter minutely upon this question, not only from the conviction that a defective supply was the most prevailing evil, but also because the amount that appeared to me desirable, in many instances, was so far beyond that which had previously been given, as to exceed it by upwards of a hundred times. In some cases, if the natural movements of the air be not impeded, sufficient ventilation may be procured; but in others, heat applied by a powerful shaft or otherwise, or a mechanical power worked by a steam-engine, may be desirable. Still, however, the great questions are, the amount of supply, and the condition and the manner in which the air is to reach and pass away from the person.

403. Thus, then, the amount of air required for ventilation forms the foundation of all ventilating operations. No system need be considered until this question be determined. It is, in many cases, a complex question, and involves, more especially, the following considerations,—

1. The condition of the constitutions to be supplied.
2. The degree of comfort that may be considered desirable.
3. The number of persons that may crowd upon a given space.
4. The quality of air that may be accessible.
5. The highest and lowest temperature for which it may be necessary to provide.
6. The system of heating that may be adopted.
7. The nature of the furniture, including all adventitious materials likely to affect the air, particularly flowers and paint.
8. The purposes to which the apartment may be applied.
9. The fluctuating demands to which it may be necessary to attend.
10. The construction of the apartment; particularly the nature of the walls and windows.
11. The system of artificial light that may be adopted.
12. The presence of local impurities.

404. In some respects, the question of the amount of air to be supplied may be considered in an economical point of view, in the same manner as the table which any one can afford to sustain, the house in which he may dwell, or the clothing which he may put on. It will not be doubted, that the more nearly the air breathed within doors approximates in purity and freshness to the free and open atmosphere, the more conducive will it be to sustain health and strength, and to prolong life. But, in cold weather, the expense in maintaining a desirable degree of warmth is much influenced by the amount of air supplied at a given time, so that purity of air is often sacrificed to warmth, with the view of avoiding expense.

405. But confining our attention to an average temperature, and to any ordinary apartment not overcrowded with many

persons, and not subject to any peculiar or noxious emanation, it is considered that 10 cubic feet per minute should be provided for each individual.

406. This estimate is given with much diffidence, and only as an approximation. It is the result, however, of an extreme variety of experiments made on hundreds of different constitutions, supplied one by one with given amounts of air, and also in numerous assemblies and meetings, where there were means for estimating the quantity of air with which they were provided. In some cases, those who became the subject of experiment were for a time included in an air-tight box, such as that represented, and provided with a long glass-pipe to enable them to draw the air they inspired from any part of the box in which they were placed. A small seat is represented on one side, and on the other a series of trays on which materials could be placed, either for the purpose of absorbing various ingredients from the air on special occasions, or of communicating different materials to it.

Fig. 138.

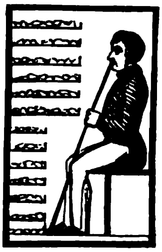
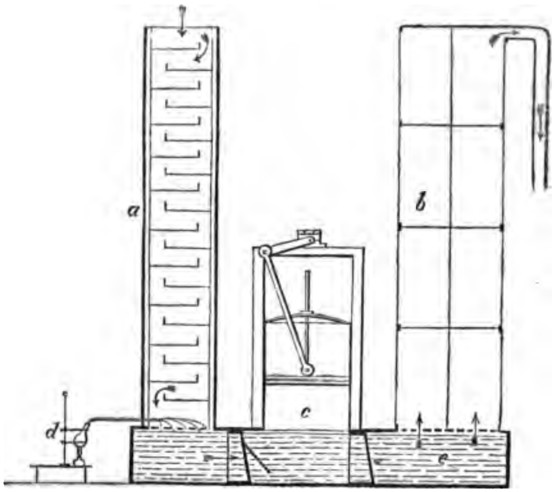


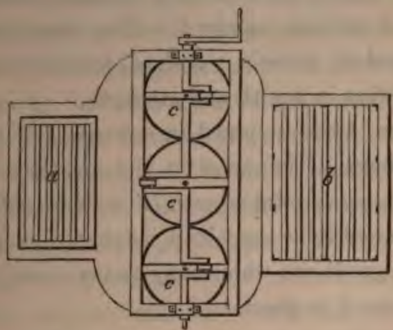
Fig. 139.



407. On other occasions, a more complicated piece of appa-

ratus was employed (Figs. 139, 140), consisting of a large iron frame, glazed like a window, and connected with a pump, by which air of any quality could be supplied by drawing it through the smaller frame, and forcing it in the required quantity into the glazed frame, which is sufficiently large to accommodate se-

Fig. 140.



veral individuals. The air entering was dried in *a*, the preparatory chamber, or charged with any peculiar materials from the flask *d*; *e* shews the progress of the prepared air from the pumps *c*, by which the quantity given was precisely measured; and *b* the glass chamber in which those were placed who were made the subject of experiment.

408. Another apparatus was also used, in which either an ascending or descending movement could be commanded, as might be required, and in the principal experimental apartment constructed in reference to the House of Commons, the atmosphere could be made to ascend or descend according to the particular purpose to which it was to be applied.

409. There are perhaps no matters on which any two individuals are less likely to agree, than as to the precise amount and quality of air which is most suitable and agreeable to them. Age, habit, temperament, diet, clothing, previous exposure and engagements, mental excitement, and the state of the constitution at the moment, all concur to modify the impression produced by

any given atmosphere upon the system; while changes induced in the system itself, within a given period, may render agreeable an atmosphere which was previously almost intolerable.

410. It is unfortunate that the standard for pure air is generally low, in consequence of the comparatively indifferent condition of the state of the atmosphere in the greater number of habitations. Hence, many judging by their own sensations, do not appeal to a correct standard. The atmosphere they have been accustomed to is their standard, not that where the constitution flourishes in health and strength.

411. Others, again, exposed in extreme situations, and subject to an amount of impurity in the air they breathe, which would certainly prove fatal to men of a less hardy constitution, cannot be supposed to be capable of judging of the minute amount of particular ingredients which may annoy those extremely who are not accustomed to them.

412. Waiving such considerations accordingly, which, if minutely entered into, would occupy a volume much larger than this work, it may be sufficient here to state, that ten cubic feet per minute appears to me to be the amount of air which should be provided for each individual, when the external atmosphere is mild and agreeable, neither oppressive from heat, nor requiring, on account of cold, the assistance of artificial heat.

413. If we look to the fact that less than half a cubic foot of air passes through the lungs of an adult in a minute, this estimate may at first appear excessive; but if we remember, that, at each expiration, a quantity of air is emitted which mingles with an additional portion of air exceeding largely its own bulk, and that there are twenty such respirations per minute, while provision is also required for the air that affects the surface of the body, and for the endless variety of minor effects produced by furniture, lighting, heating, refreshments, &c., where no peculiar adaptations for these purposes have been introduced beyond those usually observed, it will be seen that the estimate is by no means immoderate. The real question is, not what the constitution

can bear, but that amount which is conveniently accessible in ordinary habitations, and which is essential for the wants of the system.

414. The power of the system in accommodating itself to peculiar circumstances, is very great. The amount of opium, wine, tobacco, ardent spirits, and other substances, which some individuals can habituate themselves to, though only at the expense of impairing their constitutions, is no less remarkable than the varieties of atmosphere, loaded with impurities, in which others can breathe, and even work for years continuously. Perhaps the most singular instance of this kind, exclusive of those met with in polar regions, and in a rude state of society, are to be seen in mines, where it is frequently common for the men to work in an atmosphere too impure to permit a common candle to burn, though an oil lamp, in consequence of its greater tenacity of combustion, may be maintained in action without difficulty. But numerous individuals faint in an atmosphere far less impure than that of some coal-mines, and even death has been considered to have ensued in some instances from vitiated air, though it was not sufficiently impure to extinguish a candle, no impurity but carbonic acid being known to have been present.

415. In endeavouring to ascertain the amount of air generally desirable for respiration, several extreme experiments were made, from which I found that I had no difficulty in remaining from one to two hours in an air-tight oblong metallic box, not larger than was necessary to contain me in the horizontal position, and the door being carefully cemented and soldered, so that no air could either enter or escape during that period; Were chemicals employed to absorb carbonic acid and moisture, and to exhale oxygen from time to time, there is no limit to the period that life might be sustained, so far as air is necessary.

416. When numbers crowd upon a given space, and in all cases where the temperature of the air is more than usually high, a large supply of air is desirable, not only for the respiration of those present, but also for the purpose of renewing the air quickly, so as to moderate the heat produced by so many on a

limited space. In some instances, in crowded concerts, or other public meetings, individuals are not unfrequently so closely packed or wedged together by the pressure of the crowd, that it is impossible, except by powerful means, to produce a displacement of the dull and oppressive atmosphere with which they are surrounded; and few can ever have been in a dense crowd, even in the open air, without noticing, that, in particular states of the weather, the atmosphere around becomes offensive, especially during the absence of the sun, and in a calm day, when there is nothing to determine any regular movement in the air, and when the external temperature approximates to that of the human frame.

417. It appears to be universally admitted, that a low diet diminishes the necessity for much air, and that, on the other hand, where there is little air, there cannot be a great appetite for food. There are no periods accordingly, if we except a period of severe bodily exercise, where the constitution demands such a variety of supply as immediately before and after dinner; and, in the present state of society, a large share of the evil not unfrequently attendant upon a dinner party, does not always arise so much from individuals having taken more than their constitution requires, but rather from the vitiated air with which the system is usually surrounded at such periods. Some years ago, about 50 members of one of the Royal Society Clubs at Edinburgh, dined in an apartment I had constructed, where, though illuminated by gas, the products of its combustion were essentially excluded, as they were all removed by a ventilating tube connected with, but concealed in, the drop of the gothic pendant in which the central lights were placed. Large quantities of a mild atmosphere were constantly supplied, and passed in quick succession through the apartment throughout the whole evening, the effect being varied from time to time by infusing odoriferous materials, so that the air should imitate successively that of a lavender field, of an orange grove, &c. Nothing very special was noticed, during the time of dinner by the members; but Mr Barry, of the British Hotel, who provided the dinner, and

who, from the members of the club being frequently in the habit of dining at his rooms, was familiar with their constitutions, showed the committee that three times the amount of wines had been taken that was usually consumed by the same party in a room lighted by gas, but not ventilated—that he had been surprised to observe that gentlemen whose usual allowance was two glasses, took, without hesitation, as much as half a bottle—that those who were in the habit of taking half a bottle, took a bottle and a half, and that, in short, he had been compelled twice to send hackney-coaches for additional supplies during dinner, though he had provided a larger supply than usual, considering the circumstances under which the members met.

418. Minute inquiries afterwards assured me, that no headache nor other injurious consequence had followed this meeting, nor was any of the members aware, at the moment, that they had partaken more heartily than usual, till Mr Barry shewed them what had taken place. The meeting included individuals of all ages, and of extreme variety of occupations, among whom there were judges and members of Parliament, medical men and members of the bar, naval and military officers, whose different ages varied as much as their very various professional occupations.

419. Though the illustration now detailed is important, in placing in an extreme point of view the power of a pure atmosphere, supplied freely without offensive currents, the facts illustrated must be more or less familiar to all who have paid any attention to the influence of the air upon the appetite, and entirely in unison with the statements made by manufacturers, whose men are reported to have struck for wages where a good system of ventilation had been introduced, as their former wages were insufficient to procure them the increased amount of food which their appetites now demanded.

No argument indeed is more common against ventilation, among many, than the expensive appetite it maintains. It is not necessary now to go to workhouses or manufactories to trace the operations of a vitiated atmosphere in imparing the appetite,

the great attention paid to them of late years having rendered some of them examples of a fresh and wholesome atmosphere. Nowhere is it seen more distinctly than in numbers of the refreshment-rooms in which this great metropolis abounds. Many a hard-worked clerk too often imagines he has had enough for his support, because he has taken all that his appetite permitted; whereas the saturated atmosphere in which he dines may have reduced his appetite by a half, and made him contented with an inadequate supply. The profts, in numerous such rooms, would diminish largely were they well ventilated, and were the appetite equally satisfied at the same time. But the subject is as yet very imperfectly known, and escapes, in a great measure, at present, the attention of both parties. Unquestionably, however, the landlord or proprietor of ill ventilated refreshment rooms has no right to charge at the same rate as those that have their apartments well ventilated.

420. In the same manner, when a house, previously subjected to a bad atmosphere, has been well ventilated, the expense of wine and refreshment is generally considerably increased; and a fête given in an ill ventilated apartment, crowded to suffocation and saturated with moisture, is very economical in general, compared with that which has to be provided in a flowing atmosphere.

421. The more the reciprocal action of the amount of air supplied in the habitations of men in improving their appetites, and of the effect of an increased consumption in rendering essential an increased supply of air, is attended to, the more important will its influence be found in regulating the tone of health and the general strength of the constitution; but we must now advert to other considerations bearing on the necessary supply of air.

422. A free and powerful current rather tends to exhaust and waste the constitution, when imperfectly supplied with food. Farther, if its temperature be low, the want of sufficient food to produce an adequate evolution of heat by the chemistry of digestion and respiration, renders it equally important to restrain the

cooling influences of large quantities of air. But when the system is in a different condition, when the supply of food is abundant, much air is required to carry on the processes referred to, and to promote that insensible exhalation which performs so important a function in the living frame.

423. If we look to the influence of the amount of moisture in the air, it will be found to affect, in an extreme degree, the supply that the system requires. In the polar regions, as in Captain Parry's voyages, which we have already had occasion to refer to, the moisture of the breath and of insensible exhalation was condensed in large quantity from the lowness of the temperature, and the air, even in the cabins, was left accordingly comparatively dry: but in a humid atmosphere, in a warm climate, as at the deltas of many of the great rivers, the air being saturated with the moisture abounding in it, proves a comparative barrier to the exhalation from the lungs, and from the surface of the body; the balance of exchange between the system and the external air is no longer sustained in the same ratio as formerly; an extreme condition is induced, the very reverse of that which is observed in cold countries, and hence a supply of one cubic foot in these cold countries may, in some respects, prove more powerful than that of 100 cubic feet in the delta of the Ganges, in its power of absorbing moisture from the body.

424. These considerations, and the result of actual experiment in this country, which has satisfied me that a supply of 100 cubic feet of air on some occasions does not give so much relief as that of a few cubic feet in others, will shew how numerous the difficulties are in making a correct approximation as to the quantity of air that may be considered to afford an average supply. The great point should be, to study the condition of the system, the quality of the air supplied, and the circumstances under which it should be brought into action, and to make the necessary adaptations accordingly. Some circumstances are so important in modifying the necessary supply of air, that they are considered in a separate chapter.

CHAPTER VIII.

CAUSES MODIFYING THE SUPPLY OF AIR REQUIRED FOR VENTILATION.

425. From what has been stated above, it will be seen that many causes modify much the amount of the supply of air required for ventilation, among which the following must be more particularly mentioned :—

I. *Temperature.*

426. The principal point that demands attention, in looking to temperature in connection with ventilation, is the very different effect produced by the same atmosphere, at the same temperature, *according to the rate at which it moves.* The usual practice in all ordinary cases, where the state of the ventilation may be the subject of complaint, is to appeal to the thermometer. But nothing is more fallacious in respect to the influence the air may be expected to produce upon the feelings, if we trust to the thermometer alone. Air, under ordinary circumstances, in this country always exerts a cooling power upon the system, its temperature being lower than that of the human frame. If the air be stagnant, little effect is produced, because a minute quantity of air only comes in contact with the body in a given time. But if the wind blow freely, many successive quantities approaching the body within the same time, a much greater amount of heat is withdrawn, and a much more marked effect is consequently produced. An atmosphere at a

very low temperature is not dangerous in a calm; but if it begin to blow, the face or limbs may soon be frost-bitten. So far, then, as mere temperature comes into play, atmospheres perfectly equivalent in respect to their calorific or frigorific influence upon the human frame, might be obtained at temperatures varying with the velocity. An atmosphere cold and offensive to the feelings, might immediately be rendered pleasing and agreeable, by reducing its velocity; or, on the other hand, an atmosphere sultry and oppressive from its high temperature, might be rendered cool and pleasant to the feelings by increasing its velocity, provided its temperature be actually below that of the human frame. When the temperature of the air has reached that of the body, no velocity can give it a cooling power, except this be done by promoting evaporation, and when a higher temperature has been attained, it necessarily produces a greater and greater impression of heat, according to its velocity; *i. e.* according to the quantity supplied in a given time.

427. In this country, so far as I have been able to observe, a temperature of 65°, with an atmosphere moving in a very gentle stream, so as not to be perceptible, unless very marked attention be paid to it, is the most generally agreeable in rooms that are not overcrowded. But in all apartments, if the numbers on a given space be great, it is difficult to sustain a uniform temperature, unless a very great movement of air be induced within a given time. In many cases, when the movement of the air is restrained, though the temperature of air permitted to enter by the floor may be only 60°, it is found to rise to a temperature between 70° and 80° before it reaches the head, if the crowd be very great.

428. In the lower deck of a man-of-war, I have repeatedly noticed a difference of 11 and 12 degrees in winter between the temperature at the floor of the lower deck, where the air was permitted to enter, and that of the atmosphere about five feet above on the same deck, where the hammocks were suspended. In railway coaches, ordinary mail coaches, and other vehicles, during winter, a difference to the same amount may be fre-

quently observed, if the windows be shut and no ventilation permitted, between the temperature of the air around the head, and that in contact with the foot. And, in general, it may be noticed, that the play of aerial currents often presents very great differences of temperature within spaces exceedingly near, and even within the same apartment, so that, in the erect posture, the feet may be exceedingly cold, while the head is oppressed with heat; or, air may be tolerable in the body of a theatre, and oppressive, in the extreme, in the galleries; or it may be only comfortable in the latter, and intolerable from its cold below.

429. The habit, the clothing, the condition of the system at the moment, and many other circumstances, particularly the amount of exercise taken, and the extent to which the faculties of the mind are engaged, greatly influence the desire that may be entertained for maintaining the air at particular temperatures.

430. Some constitutions appear to be endowed with a power of resisting extremes of heat and cold, which in a short time would prove fatal to others; and it must be evident, that the functions of their frames must enable them to produce more heat than other individuals can do, or that a less supply is adequate for the wants of their system.

431. Again, the constitution of the same individual may occasionally undergo great changes from particular circumstances, such as, periodically, and on a smaller scale, it experiences in a single day from the varied occupations in which he may be engaged.

432. A native of this country, on going to a colder climate, may be seen continually exposing himself at first, without injury or inconvenience, to temperatures such as the inhabitants do not think of encountering, without an amount of protection considerably beyond that which he thinks of using. In the same manner, if he shall have been long in India, he does not feel the severity of the cold so much during the first winter, as in the second or third winter after he has returned home; and in

colder climates it is familiarly known, that by exposure to a powerful fire before undertaking short journeys, where the system is exposed to considerable severity of cold, the traveller appears to derive more benefit from it than is considered sufficiently accounted for by the mere amount of heat which may have been communicated. Many are of opinion, that some farther and peculiar change is developed in the body by the action of excessive heat, but no satisfactory explanations have been given, and a more minute inquiry is still necessary to establish all the facts of the case.

433. In conclusion, it may be stated, generally, on this point,—

1. That a temperature of 65° is the most generally agreeable to those who are not engaged in bodily exercise.

2. That the demand for heat varies extremely in different individuals according to constitutional peculiarities, diet, clothing, and many other circumstances, as exercise, excitement, and time of life.

3. That, in the same individual, the temperature most agreeable to him often varies many successive times during the day, according to the manner in which he is occupied.

4. That the temperature should be lower and lower, the more recently any refreshment may have been taken, and the larger the amount consumed.

5. That when the constitution is exhausted by long continued watching and attention to objects involving no bodily exertion, the temperature may be elevated advantageously by several degrees.

6. That the velocity of the movement of air around the person is an essential element in all questions as to temperature.

II. *Moisture.*

434. Next to temperature, few circumstances exert so marked an effect upon the influence which air exerts upon the human frame, as the amount of moisture associated with it. In consi-

dering this question, it must be remembered that the whole surface of the body, as well as the interior surface of the lungs, may be considered as a vast and extended field covered with millions of millions of pores, from which moisture is continually escaping in certain states of the atmosphere, while on other occasions it may be absorbed. A certain amount of evaporation is essential to health, and, in particular, for effecting or facilitating the discharge of various materials that accompany the moisture exhaled from the living body. The odour of numerous substances becomes apparent in the breath of the lungs, very soon after they have been taken into the system ; and it is not unreasonable to suppose that various peculiar materials of an animal nature may be discharged through the same channel, though their precise nature may be unknown. Farther, the mere evaporation of water from the surface of the lungs and of the skin must be attended with important results, relieving thereby the system from any superfluity, and affording, at the same time, marked relief in warm weather, by the reduction of temperature that accompanies evaporation.

435. But air saturated with moisture could not dissolve any more, were its temperature not elevated as it comes in contact with the body. If air be already at the temperature of 98°, and saturated with moisture, it cannot promote any evaporation from the body; but, if saturated with moisture, at 50° or 60°, it exerts an increased dissolving power as it rises in its temperature when warmed by contact with the frame, and its ultimate dissolving power bears a proportion to the amount by which its temperature is so elevated, and the quantity of moisture previously associated with it. The drier the air, the greater is its dissolving power, when it has attained that temperature which it receives by contact with the body.

436. In winter, the air, when extremely cold, is proportionally free from moisture. Its temperature could not fall without this being accompanied by the deposition of a large amount of moisture, should it previously have held it in solution. What, then, is the effect of such cold and dry air ? The moment it

comes in contact with the body, it rapidly dissolves moisture from it; and so quickly is the moisture taken away, especially if the temperature of the air shall have been previously increased (before it touches the body), that the skin is left harsh and dry, the nostrils and fauces are similarly affected, they feel dry and dusty, and a disposition to cough ensues. These are the natural effects of dry air acting upon the system; the very moisture that is essential to the membranes that line the cavities mentioned is partly evaporated, and they lose some of these physical qualities that are necessary for the due performance of their functions. But, if such air had been heated by the approach of spring and summer, what would its condition then have been? It would have been more moist. It would have picked up moisture from the ocean or from the moisture of the ground with the returning warmth of the season. Hence, then, such air could not have become warm by natural operations, without, at the same time, acquiring moisture from external sources. We are, therefore, emphatically told by such illustrations, that if we warm air artificially, we ought to communicate moisture to it before permitting it to approach the human frame. The true time, accordingly, when moisture ought to be applied to air, is not when it is warm in spring and summer (unless in very hot climates with the view of reducing temperature), but as it is warmed artificially in winter.

437. It is commonly said, that air is damp in winter, but here it is most important to distinguish between the dampness produced by moisture and precipitated from air by cold, which approximates to rain, and is therefore mechanically mingled with the air, and the moisture held in perfect solution or association with the air in summer. The air feels drier in summer than in winter in this country, not because there is more moisture in the air in the winter,—the reverse is the case; but because the dampness is precipitated upon us in winter, whereas in summer, though the amount of moisture be greater, the higher temperature gives it a more perfect solution, and diminishes its tendency to leave the air and pass to the human frame.

438. Few circumstances exert a more marked and powerful influence upon the frame among those who may pass from one climate to another, than the amount of moisture in the atmosphere. We have only to look to the magnitude of the functions of respiration and transpiration, and to the sudden changes that may be induced in the system by passing to an atmosphere more or less absorbent of moisture, or more or less powerful in promoting evaporation. And if a change of diet and habits be not made in unison with the great change of physical condition in the elements with which the body may be surrounded, disease must be considered the natural result of the changes that may have been encountered.

439. An atmosphere loaded with moisture may still be capable, as has been mentioned, of dissolving more as its temperature is raised; and even though the increase of temperature be very slight, still it will be sufficiently apparent, that, if the quantity of air brought in contact with the body in a given time be greatly increased, the amount of moisture dissolved will also be increased; for as, in a windy day, evaporation proceeds with a rapidity proportional to the quantity of fresh air that passes over a moistened surface in a given time, and the dryness of the passing air; so, in the same manner, a large amount of air, comparatively moist, may dissolve as much moisture as a smaller amount of dry air.

440. Again, moisture developes the power and activity of many substances that are often otherwise comparatively inert.

III. *Light.*

441. The influence of light upon the human frame has not been studied with that minuteness which the subject deserves. Nevertheless, many circumstances are known, from which there is reason to believe, that it exerts as powerful an influence upon the animal economy as it does in the vegetable kingdom.

442. Instances have been detailed, where the influence of light has been considered to have prevented disease; one in

particular may be noticed, which Sir James Wylie, of the imperial Russian service, pointed out to me at St Petersburgh, in one of the barracks there, in which about three cases of disease occurred in the dark or shaded side of the barracks for one in the other, though the apartments in both of these sides communicated freely with each other, and the discipline, diet, and treatment was in every respect the same. Again, many individuals labouring under asthmatic affections are extremely sensitive to the action of light, and often feel as if some sustaining power had been withdrawn from them, when they are removed from the light. In many cases also, I may add, that I could not resist the impression, after various experiments on my own respiration, that I recovered more rapidly when exposed freely to light as well as to air, than in any other way. In cities placed on the sides of hills, or on both sides of a river, with precipitous banks, medical men have observed that houses not much subjected to the action of light are those in which disease most frequently occurs.

443. Again, as bodies having different colours radiate very different rays of light, it is fair to infer that they must, in some respects, affect in different ways the varied materials upon which such light may fall. And if modern times have shewn the powerful and extraordinary daguerreotypic influence exerted by the rays of light upon dead and inert mineral bodies, it may be concluded that the living and sensitive animal fibre is still more sensible to its operation.

444. I have been informed by Mr Hay, of the Edinburgh ropery works, that, in certain seasons, and under peculiar circumstances, the rays of the moon exert a much more powerful effect in bleaching flax in a single night, than the bright light the sun exerts in successive days at the same period. Dr Stark has also shewn that different coloured cloths are prone to absorb and retain, with various degrees of intensity, different kinds of odorous matters; and dyeing operations which succeed well in one country sometimes prove a complete failure in others, from the intensity of the rays of light being different in each.

445. Further, direct experiments in white, black, green, and other painted rooms, have also led me to imagine that a very different influence is produced upon the body by rooms differently painted, though they may be precisely similar in other respects.

446. These considerations, and many others that might be added, have led me to join with those who not only consider a positive and important physical effect to be produced by light in its action upon the human frame, but that there may be other powers constantly in action upon the system, whose precise nature or influence it may be difficult to explain or define with precision. Every human being necessarily exchanges rays of heat and light with every other whom he may recognise, and without entering upon cases where it is obvious that the imagination has been powerfully affected, there still appears abundant evidence to shew, that, as yet, we are only approaching the threshold of investigation, in reference to some of those sources of power whose operation on the system has been unequivocally demonstrated.

447. In the vegetable world, the powerful influence of the rays of light in promoting the evolution of oxygen and the absorption of carbonic from the air, has long been familiarly known, and it is not unreasonable to presume, that the distressing effects which have been noticed in some invalids, when light did not play freely upon the person, may have depended on minute changes taking place under the influence of light, which did not ensue, or at least were of a different character from those that proceeded in the dark.

448. Again, many constitutions are so sensible to the influence of different species of radiations, that those proceeding from particular lamps affect them powerfully, compared with those that proceed from others. And independent of the amount of heat that may emanate from them, and which may be a special cause of offence, even the condition in which the light escapes has a marked effect upon some individuals, —obscured glasses, and those refracting unequally, producing a painful sensation to

many who can look with satisfaction on the well defined outline of a naked light.

449. It would be difficult to specify the precise extent to which such causes influence the amount of air necessary for ventilation; but every thing that increases the temperature, and the activity of the system, and induces any kind of uneasiness, is almost invariably relieved, to a certain extent, by increasing the amount of air supplied, though it is perhaps impossible for any one but the individual himself to say precisely the condition of atmosphere that is most congenial to the feelings under such circumstances.

IV. *Electricity.*

450. The extreme and intimate connexion that subsists between the electric condition of all kinds of matter and the other physical changes of which they are susceptible, has become too well known of late years to require any extended notice in this place, more especially as precise facts, which lead to valuable results in practical operations bearing on health, are not yet numerous.

451. A very large body of information has been procured, however, which proves the incessant change in electrical operations going on at the surface of the globe; and in the proceedings of the London Electrical Society, as recorded in the interesting journal published under the direction of the society, important observations connected with the electrical state of the atmosphere, the state of the weather, and the presence of disease, have been made, which will probably lead to very curious and useful conclusions, in respect to the effect of electrical influence in sustaining health or inducing disease. An extract has been given in a former page (165), to shew the general nature of the observations recorded. As a general summary, it may be convenient to bear in mind the following circumstances;—

1. Electrical changes accompany all cases of chemical action.

whether they ensue in the mineral kingdom, or in the varied changes connected with animal and vegetable life.

2. The body may be excited positively or negatively, or it may be neutral in respect to the materials with which it is surrounded. Its precise electrical condition probably fluctuates incessantly with change of diet or exercise, as well as in connection with atmospheric changes.

3. Particular ridges, hills, or other districts, may be peculiarly subject to atmospheric electrical changes.

4. In many places, but more particularly in hilly countries, the electricity may often be noticed descending in a stream, when the fingers are held up in the air, a rustling noise being perceived, not unlike that which is produced by approaching the hand to a powerful electrical machine.

5. Brilliant sheet-lighting in one place, generally indicates a powerful thunder-storm in another and more distant situation.

6. Some constitutions are much more prone to electric excitation than others, or much more easily affected by electric changes. The state of the clothing also affects much the electric condition of the body. Some individuals placed on an electric stool, and surcharged with electricity by the common electrical machine, evolve electricity so freely that scarcely any symptoms can be obtained of its presence on applying a conductor; while others, with a similar charge, give abundant indications of its presence, as it does not pass off so readily from them to atmospheric air. In passing the electric shock through a number of individuals, it has been ascertained that some persons are much better conductors of electricity than others.

7. When the body is in a high state of electric excitation, the air around it is changed freely and rapidly by the influence of the electricity upon the surrounding particles of air. But, when the system is not much exerted, the air is apt to stagnate around the person.

V. *Pressure.*

452. The human constitution appears to have the same faculty of accommodation to the varied pressure of the atmosphere which it also exhibits in respect to heat, moisture, and other atmospheric influences. Every variation from the ordinary range of density to which it is subjected, must necessarily induce peculiarities of tension throughout the whole frame, and affect more especially the cells of the lungs, the pores of the skin, and the cavity of the cranium. It cannot be questioned, that some of these sensations which are familiar to every constitution, but more particularly to the invalid, and which are dependent on a change of weather, are more peculiarly associated with a rise or fall in the barometer. In asthmatic cases, this may be particularly noticed, and also in others connected with disease in the respiratory organs. The tendency to exhalation from all surfaces, and the amount of expansion in all the more compressible tissues, must unquestionably increase with the fall of the barometer. The relief afforded in peculiar cases by a change in the pressure of the atmosphere, is abundantly testified by the results of the daily experience of medical men; and cases are not wanting where patients have placed themselves for considerable periods in atmospheres of peculiar density, which have given decided relief, these atmospheres having been produced by the action of air-pumps, which gave the density required. The patient must be placed virtually within the receiver of a forcing or exhausting air-pump; though, from its magnitude and form, as well as the materials of which it is composed, it may bear little resemblance to the ordinary air-pump receiver.

453. The amount of air supplied to the blood in the lungs must obviously vary at each inspiration, according to the density of the atmosphere inspired. From this cause, then, more air, by more frequent inspirations, may be requisite when the barometer is low, that a proper supply may be obtained.

454. It will also be apparent, on considering the influence of the pressure of the atmosphere, that hœmoptysis may be appre-

hended to increase on a sudden fall of the barometer, from the diminished resistance which the blood-vessels present to the pressure of the blood within ; and the annals of medicine notice various cases in unison with this opinion.

455. But the influence of a variation in the height of the barometer, is, perhaps, more familiarly known by its effects upon stagnant pools and marshes, and all materials loaded with gaseous products, whether formed by the process of fermentation, putrefaction, or other operations. The effluvia from drains and marshes, and the fire-damp of mines, may be taken as well-known examples of matters subject to such changes. If these be, in a great measure, pent up, by the pressure of the atmosphere, in those bodies from which they are discharged, the amount evolved being comparatively trifling, a sudden fall of the barometer immediately causes their liberation, which is much more excessive at first than afterwards. But a rise of the barometer is equally accompanied by a diminution in the facility and rapidity with which such products are evolved.

456. The influence of the pressure of the atmosphere is accordingly most important in low, confined, and marshy situations, subject to unwholesome exhalations ; the greater the extent to which the barometer falls, the greater is the necessity for providing against the emanations that then ensue.

In addition to the more general causes modifying the air required for ventilation, which have now been enu-nd the purity or impurity of the air respired, many iously present themselves to our consideration which y important, and without attending to them ventilation ot proceed satisfactorily.

58. Among these we may enumerate,—

Age,
Temperament,
Habit,
Health and Strength,
Diet,

Excitement,
Previous Exposure,
Mental Anxiety,
Artificial Illumination,*
The Nature of the Occupation,
Exercise,
Fatigue,
Clothing,
Draughts and Currents.

All these, and numerous others which might be mentioned, were we to enter more into detail, especially the impurities or nature of the exposure in particular workshops, manufactories, or out-door works, must evidently tend to influence the amount of air that is grateful to the system, and desirable for health. It is only necessary here to state, that, when any vitiated air is produced by a gas-lamp, or other artificial lights, or by any manufacturing operation, or any minute dust from iron, stone, or any other material, too much importance cannot be attached to the desirableness of involving it directly in a stream or current of air, by which it is conveyed to a channel where it cannot possibly contaminate the air of respiration.

459. This direct removal of noxious products, renders the change of the whole atmosphere, by any extended measures beyond those required for ventilation, altogether unnecessary. If the products referred to once mingle with the general atmosphere in which they are produced, though they may be much diluted, it is more expensive in this, than in the preceding manner, to sustain a wholesome air, from the quantity that must be removed to maintain it tolerably pure.

* Some individuals are very sensitive to the nature of the radiation from particular lamps, even where the products of combustion are completely removed.

CHAPTER IX.

ON VITIATED AIR.

460. Air is apt to be contaminated with numerous impurities, natural and artificial, which would soon accumulate, in particular districts, to such an extent on the surface of the ground as to render it unfit for use, were they not dissipated and diffused through the great body of the atmosphere, by movements consequent on their production, and by the wind, or consumed by processes which tend perpetually to alter such products, as constantly as they are developed, and maintain the atmosphere in its usual condition. In a practical point of view, the following impurities require most frequent attention, in connection with the history of ventilation.

I. Carbonic Acid Gas.

461. This compound is heavier than air; and is by far the most common impurity met with in the atmosphere, being formed during respiration, by the combustion of all carbonaceous compounds, by putrefaction, fermentation, and numerous operations of art and nature; in particular, it is evolved in enormous quantities by some volcanoes. It cannot support respiration nor combustion. Any animal, placed in an atmosphere of carbonic acid gas, falls down insensible, and, if not speedily relieved, soon dies. If the body be surrounded with this gas, and pure air be 'upplied to the lungs, the skin assumes a reddish appearance, q irritated by the action of the acid.

In general, when any attempt is made to inspire pure cid, a convulsive movement, induced at the entrance to

the windpipe, closes the aperture, and prevents its ingress. In some cases, there is reason to believe that the movement has not been sufficient to exclude the carbonic acid, and immediate death has ensued. It is not known that there is any hope of recovery, where carbonic acid freely enters the lungs. Where fainting is induced, at first, the gas being altogether excluded, or where the gas enters in a state of considerable dilution, death is not necessarily immediate, even where it may ultimately ensue. Some individuals work habitually in mines and other places, where from one to two per cent., and perhaps still larger quantities, of carbonic acid are present. But death has ensued in some peculiar cases, it has been affirmed, where there was only one per cent. Any ordinary atmosphere containing one per cent. of carbonic acid, must be regarded as of very inferior quality, and not fit to sustain health, though in numerous apartments a much more vitiated air may be observed. Air containing ten per cent. of carbonic acid, and other impurities of less note, a considerable amount of moisture, and, at the same time, at a high temperature, constituted the most impure atmosphere charged with carbonic acid to which I have been exposed; nor am I aware that I could have resisted its action for any considerable period, had its influence not been gradually developed, as the pure air in which the experiment began had successive quantities of carbonic acid communicated to it.

463. When carbonic acid is present in smaller proportion than is necessary to produce an immediate and overwhelming effect, it induces a trifling headach or intolerable oppression in endless gradations, according to constitutional peculiarities, and different circumstances connected with the state of the atmosphere in which it acts. When consciousness begins to return after the more severe influence of an atmosphere almost sufficient to cause death, has passed away, the sufferer is sometimes for hours unable even to moan, so as to attract the attention or give warning to those in adjoining apartments, and the head feels literally as if it were a mass of lead, chained immoveably to a rock from which it cannot be liberated.

464. The system may be become habituated to the action of air charged with increasing proportions of carbonic acid, in the same manner as it can be accustomed, by long habit, to excessive quantities of beer, wine, spirituous liquids, opium, and other substances; and hence individuals may be constantly observed with all their faculties in full activity, in an atmosphere that almost induces a soporific effect upon others not accustomed to it; but a general reduction of strength, and firmness both of mind and body, accompanied by an inferior appetite, invariably attends long and frequent continuance in such atmospheres.

465. The hygrometric condition of the air affects much the influence of carbonic acid.

466. The long-continued action of a small proportion of carbonic acid, which does not produce much annoyance at first, may ultimately produce the most injurious consequences.

467. The lower the tone and strength of the constitution, the more alive does it become to the depressing influence of air contaminated with carbonic acid. The old and infirm sometimes sink in an atmosphere of which the robust and vigorous may take no notice.

468. When the quantity of carbonic acid is reduced to a proportion, varying from 1–1000dth to a 1–2000dth part, it does not produce deleterious results. Common air contains a minute proportion of carbonic acid, even at the highest altitude at which it has been examined.

469. Carbonic acid, though heavier than air, does not separate from it, as many still suppose, after it has once mingled with the air during the process of respiration or combustion. Carbonic acid, when pure, or air largely charged with it, tends to fall on the ground like water, when poured from any vessel into the open air, as it is produced in breweries, in old wells and pits, in the Grotto del Cane, in the Valley of Death, and similar situations, or during combustion in a limited atmosphere, and in experiments in the laboratory. In all cases where the

amount is considerable, it tends at first to accumulate in cavities on the surface of the ground.

470. No proof has yet been afforded that it ever separates from the air, except by the operation of special agents, when it has been once diffused through it. (See Diffusion of Gases.)

471. Carbonic acid being the principal impurity communicated to air in all ordinary apartments, the amount present may, in general, be taken as an index of the state of the atmosphere, and of the efficiency of any ventilating arrangements. During the last seven years, I have constantly applied tests for carbonic acid for this purpose, and in some cases fifty individuals have taken specimens of air from different buildings at the same time, and, on looking to the indications presented, any one could tell the leading character of the atmosphere from which the specimen was taken. It is scarcely necessary to remark, that a precise analysis is not requisite for ordinary purposes; but an approximative estimate may be easily formed, with apparatus so simple, that any one, with very little trouble, might test the air for himself.

472. At the same time, I must mention, that, in a very remarkable case where the air was very oppressive, in an extremely crowded apartment, I found but little carbonic acid, so that I have been led to imagine, that, under peculiar circumstances, the evolution of carbonic acid may be diminished to a certain extent. In another case, which presented to me the most offensive atmosphere I recollect to have encountered, viz., that in a dark and almost air-tight cell in a prison at Stockholm, where a refractory person had been confined for a considerable period, who looked wild and alarmed as the door was opened, there was only a minute trace of carbonic acid. With these two exceptions, which have not shaken my confidence in the general result of the indications I have obtained, I have always found the amount of carbonic acid in unison with the impurity of the air in ordinary apartments. When the system has been exhaling moisture freely in an atmosphere well adapted for this purpose, and in a flowing current of air which facilitates eva-

poration, the sudden stoppage, or at least the great reduction, in the amount of exhalation that must ensue, both from the lungs and from the surface of the body, on a sudden transition into an apartment containing an atmosphere saturated with moisture, must, of itself, be a source of great uneasiness, even where the amount of carbonic acid may be trifling. There are cases also, where minute quantities of gas, or of particular odorous effluvia, are extremely offensive to some individuals, while others are not sensible of them.

II. Carbonic Oxide.

473. This gas is produced in cases of imperfect combustion, where there is much carbonaceous matter; it is very commonly evolved from all cinder-fires in a low state of combustion. Where a blue flame is seen upon the surface of the fuel, the carbonic oxide is subsequently consumed. It has been considered by many to be still more violent in its action on the animal economy than carbonic acid, but it is difficult to draw comparisons, where few trials have been made, the result having been nearly fatal in the only experiment recorded. Carbonic oxide contains the same elements as carbonic acid, but less oxygen. In all cinder or coke fires, having a thick bed of fuel, carbonic acid is formed below, and changed into carbonic oxide, as it receives carbon from the fuel above. It is inflammable when heated, consuming oxygen and producing carbonic acid.

474. Coal-Gas is fatal to animal life; minute quantities are very offensive to many constitutions, and offensive also from the odorous or oily matters, and other impurities, often associated with it. In mines, the fire-damp is not so offensive to the smell as ordinary unpurified coal-gas, though equally destructive of life when the body is immersed in it. Miners constantly work in atmospheres where a very considerable proportion of fire-damp is present. The fire-damp is more uniform in its composition, and contains less carbon, than coal-gas prepared artificially; the latter also contains different combinations of carbon and hy-

drogen. Coal-gas, evolved in an open stream from a wide tube, accumulates in the upper part of any still atmosphere, and may form an explosive atmosphere at the ceiling of apartments, when that on the level of the floor is comparatively free from it.

III. Sulphureted Hydrogen.

475. This is a frequent emanation from numerous manufactories, particularly from gas and other chemical works. A quantity, so small as not to exceed 1-15,000dth part, has been known to produce injurious effects on the constitution. Moistened carbonate of lead is darkened by air containing only 1-20.000th part. To some individuals, air containing only 1-1.000.000th part, or even less, has proved offensive; a horse dies in air containing a 250th part, and a bird in air containing 1-1500th part. Various animals have been killed by surrounding the body with this gas, though fresh air was supplied to the lungs. This gas is produced from sulphureous compounds, when acted on by different substances, according to the condition of the sulphur, and the materials with which it is combined. It is a common product of the putrefaction of animal matter, and also of sea-water, when subjected, in a limited atmosphere, to the action of organic matter. Lime or mortar, which has been long exposed in drains, frequently evolves it abundantly when mixed with an acid.

476. Dr M'William of the Niger expedition, has shewn that sulphureted hydrogen is not contained in the waters of the Niger, and in numerous other specimens of water; though the same waters, if kept in corked bottles to which a little air has access, uniformly produce it. In bottles hermetically sealed, and containing the same waters, no sulphureted hydrogen is produced.

IV. Sulphurous Acid.

477. This compound, and sometimes sulphuric acid, is evolved

in many chemical manufactories, and in certain processes for consuming the products collected in purifying gas. It is the same offensive suffocating gas that is produced on burning sulphur. It is much more irritating than sulphureted hydrogen, but perhaps not so very pernicious to animal life.

V. Hydrochloric Acid.

478. Hydrochloric (termed muriatic formerly) acid is perhaps disengaged in larger quantity in chemical manufactories than any other corrosive acid. It is produced, and sometimes discharged, to the extent of tons daily in black-ash (British barilla or soda) manufactories, and is offensive to animal and vegetable life. I have, on some occasions, tested it very distinctly in the air at the distance of two miles from the manufactory, where it was discharged by a lofty chimney. The less lofty the chimney, the greater the degree of concentration in which it falls upon the ground, and the less the distance to which it is carried. The loftiest chimneys for manufacturing purposes in this country, are for the discharge of sulphurous and hydrochloric fumes. The largest and tallest hitherto built, is at Mr Tennant's chemical-works at Glasgow. It is 400 feet in height, about 50 feet in diameter at the base, and 12 feet at the top. It works numerous furnaces, besides discharging offensive products.

479. Hydrochloric acid being largely condensed by water, is in some cases conveyed from different manufactories to the water of adjoining rivers, where it is rapidly absorbed. Where the flow of water is considerable, and the water loaded with impurities, the acid may exert rather a beneficial influence than otherwise; but where the stream is very small, in proportion to the amount of acid vapours conveyed to it, the effects may be injurious. In some cases, innumerable fish have been poisoned where they came in contact with the acid, before it had become sufficiently diluted.

VI. Ammonia.

480. Ammonia is a very common impurity in air, wherever animal matter in a state of putrefaction is observed. It is very frequently associated with animal matters, upon which it may exert a power of solution, though its precise influence in this respect has not been so minutely investigated as the importance of the subject demands. It is also frequently combined with carbonic or other acids.

VII. Impurities from Arsenic, Copper, and Lead.

481. These metals are often suspended in different combinations, principally as oxides, and in minute and various proportions in the vicinity of manufactories, where they are subjected to chemical operations. The state of the vegetation in the vicinity attests their poisonous influence. Sulphureous compounds usually accompany them. The hardening of tallow by arsenic, so as to make it resemble wax, has led to a new source of impurity in the atmosphere of ordinary apartments, which must be productive of the most deleterious results, especially where inefficient ventilation adds to the evil.

VIII. Impurities from Putrefaction, Disease, Malaria, and Contagion.

482. Besides the definite compounds referred to above, and all those that may emanate from special causes, the living body, when under the influence of certain varieties of disease, and animal and vegetable matter generally, when in a state of putrefaction, tend to produce compounds, whose precise nature is in general very imperfectly understood, but which are prone to develope diseases of different kinds, according to the nature and amount or virulence of the poison generated. A case of small-pox illustrates well the great effect that can be produced by a minute portion of a specific virus; many other diseases may be

communicated by inoculation, in the same manner as this was too often propagated in former times; and there appear to be many reasons for believing that a great variety of peculiar products are formed, both by animal and vegetable matters, each capable, under favourable circumstances, of producing a specific change, or series of changes, such as a portion of yeast or ferment induces in a liquid capable of undergoing the vinous fermentation. Malaria or miasma, produced by decayed vegetable matter, may probably thus be regarded rather as a generic term, as the malarious or miasmatous products may be as varied as the different specific poisons which are known to be generated in the animal economy. And the same poison may produce a variety of effects, according to the circumstances under which it is brought into play. Acting in one place and on one constitution, the miasma of marshes, in the opinion of some medical men, may produce ague, but in another, intermittent fever, remittent fever, or even typhus. Whatever may be the precise constitution of such matters, their origin indicates that they must be composed of oxygen, hydrogen, carbon, and nitrogen, or of some of these to the exclusion of others. Oxygen is probably not a predominating ingredient. This agent, indeed, is always tending, when freely supplied, to decompose them, and resolve them into water, carbonic acid, and nitric acid. Their decomposition, also, in some cases, by chlorine and heat, indicates the composition mentioned. In studying the effects of miasma, it should not be forgotten, that, as volcanic dust and the sands of the desert have been carried in some cases to the distance of many hundred miles, so also the more minute and subtle poisons of miasma and contagion may perhaps be carried to a still greater distance, and occasionally develope diseases where there may be no apparent cause.

IX. Mechanical Impurities.

483. These are in general too obvious to require much explanation. In large towns in this country, there are generally three great sources of mechanical impurities: the degradation of

materials in the street, the ordinary impurities that collect there, and the soot produced by the imperfect combustion of coal. The latter will be considered under Combustion and the Prevention of Smoke.

484. To remove the former, an improved system of drainage and cleansing is essentially necessary in many large cities. Where water is used in such small proportions as only to allay dust, in some cases, in warm weather, its use is accompanied with an evil almost as bad as it obviates,—viz. the production of a steam or vapour, loaded with the products of decomposition. The copious use of water, so as to remove and float away impurities, has been found highly advantageous; but arrangements for such a supply are at present too expensive, and as yet rarely introduced in this country. Whitworth's sweeping machine has been introduced very successfully in the crowded districts of large cities. From a minute investigation, it appears that very large sums of money are annually lost by the inhabitants of populous cities, from the imperfect measures adopted for cleansing streets. In a statement made to one of the societies in the metropolis, it appears that the proprietor of Mivart's Hotel considers that the extra cleaning for which he has to pay from this cause, costs him several hundreds of pounds annually.

X. Impurities from Furniture.

485. In ordinary apartments, many varieties of furniture often influence the air that comes in contact with them to such an extent, that it has always an unpleasant smell, and seems destitute of freshness and elasticity. This source of impurity becomes still more offensive, when the moisture, carbonic acid, and other products of exhalation, respiration, and artificial illumination, in crowded apartments, are not carried off, but deposited during night as an impure dew upon the furniture.

486. Some dyed stuffs, used for furniture, often have an offensive odour, from the nature of the materials employed in preparing them, which adhere for a long period to them, if not de-

stroyed by a high temperature, or by the action of special chemical agents.

487. Newly painted and varnished rooms and furniture are often exceedingly offensive to some constitutions, and retain their odour for a long period, if not subjected to a brisk current of warm air, that all the volatile particles may be evaporated and dissipated as soon as possible. The popular remedies of a tub of water and a bundle of hay have some trifling influence, in so far as they can absorb and condense a portion of such odorous matters, as is distinctly indicated by the smell which they soon acquire in these apartments. But it is obvious that they can only acquire the odorous particles through the medium of the air; and accordingly it is much better to dissipate them at once by ample ventilation, after facilitating their evaporation by a proper elevation of temperature. Where rooms are to be occupied soon after they are painted, the nature of the paint and varnish used should be very carefully selected. In some public rooms, I have seen a bad varnish continue to give out an offensive odour for nearly a twelvemonth.

488. In the same manner, if proper ventilating apertures were freely opened in halls and public assembly rooms, so as to discharge thoroughly, each time any audience may have retired, all the vitiated air that may have accumulated in them from respiration, and the combustion of lamps and candles (where these products are not removed from first to last by systematic ventilation), one of the most common causes of decay of furniture, and of dry rot in the roofs of buildings, would be removed.

489. The other varieties and causes of vitiated air are as numerous as the endless chemical changes by which they are produced, and the local circumstances under which they take effect. See *Smoke*, *Drainage*, and *Destruction of Nuisances from Manufactories*.

CHAPTER X.

1. PURIFICATION OF AIR.

490. All measures that tend to improve general cleansing, sewerage, drainage, the prevention of smoke, and ventilation, necessarily contribute much to the improvement of the air in those districts in which they are introduced, and, by conjoining with these the means for withdrawing or destroying noxious impurities evolved from sewers and manufactories, much might be done in numerous large cities to remove some of the greatest sources of offence that contaminate the atmosphere.

491. In many manufactories, materials are evolved, which, if subjected to the action of an elevated temperature before they pass into the open air, are rendered entirely innocuous, or, at all events, produce no offence beyond that developed by the ordinary products of combustion. Thus, at Burntisland, a small seaport about ten miles from Edinburgh, a manufactory of whale-oil from blubber was carried on not long ago, where all the noxious matter usually evolved was completely destroyed by being drawn through red hot cinders, supplied freely with air at the same time; but when this arrangement was not in force, the offensive odour from the manufactory was perceptible at the distance of miles, in the direction of the wind. Similar arrangements have long been applied by M. D'Arcet of Paris to the melting of tallow, and other operations, and might, with much advantage, be more generally introduced.

492. In crowded cities, where the general purification of air may be deemed most desirable, and in the vicinity of manufacturing operations, or where peculiar offensive products may

be developed, the following are the principal arrangements which I have adopted :—

I. The exclusion of soot, by drawing the air through very large veils made of porous materials, thickly beset with fibres, which intercept the suspended soot.

II. Washing with water, so as to remove more effectually the smaller particles—the air being forced to pass through an artificial shower.

III. Washing with lime-water, to produce a similar effect, and to condense acid gases, more especially sulphurous, carbonic, and hydrochloric acid gas.

IV. An admixture of ammoniacal gas, to assist in producing similar effects.

V. An admixture of nitrous acid vapour, and chlorine gas, to decompose animal and vegetable matter. The figure given in describing the washing-chamber in the House of Peers, illustrates one of the varieties of washing apparatus, and, along with the remarks on the Niger expedition, various arrangements provided for the purification of air, are shewn. The medicator was used principally for such purposes, and for producing artificial atmospheres.

VI. A copious admixture of steam, or the production of an elevated temperature by other means.

VII. Where peculiar local products have been evolved, then special means have often been resorted to with the view of counteracting their influence, if this could be economically effected.

493. While I have resorted to the means mentioned above on numerous occasions with advantage, and the usual application of lime-washing and fumigations in the more urgent cases, it will be found still more important, wherever it is practicable, to endeavour to exclude impurities in the first instance, to neutralise or decompose them before they mingle with the air, or to destroy the materials from which they may emanate, by forming them into new chemical combinations.

494. The addition of chemicals to atmospheric air, the effectual mixture of these with the impurities upon which they are to act, or the regulation of the proper proportions, all presume a series of arrangements such as can be effected only when systematic ventilation has been introduced, and when a knowledge of chemical details can be depended on. But good and efficient drainage, the destruction of putrid exhalations by lime, efficient cleansing, and the removal of offensive accumulations that contaminate the air, strike at the root of the evil, and do not necessarily require any professional knowledge. The following memoranda, as to lime-whiting and fumigations, should be familiar to all that direct their attention to such subjects.

495. It must also be remarked here, that too much attention cannot be paid to the situation selected from which fresh air is derived in ventilating any building; on investigation, it is often found that some sides or parts of the building afford much less objectionable air than others; but this point has been adverted to in a former part of this work.

496. Lime-Whiting owes its efficacy to the causticity of the lime used for this purpose, and to its action on solid or liquid impurities on the walls, whereas gaseous fumigations affect principally the mere temporary condition of the atmosphere. Chalk is of no value, comparatively speaking; in it the lime is already carbonated (combined with carbonic acid). But lime, that is, chalk or limestone deprived of carbonic acid, tends to acquire that carbonic acid again from the atmosphere, and from all animal and vegetable matters with which it is mingled, their carbon and oxygen, assisted under certain circumstances by the oxygen of air and water, tending to unite, so as to form the carbonic acid by which the lime becomes carbonated. Other acids may at times be formed, but that is of no consequence, so long as the offensive animal or vegetable matter is decomposed. Further, the caustic lime is destructive to innumerable animalculæ, causticity, in chemical language, signifying a power of decomposing or disorganizing the vegetable or animal products brought into contact with the caustic. When the lime becomes

carbonated, it loses its causticity, and a fresh lime-whiting is necessary. The more fresh and recently slacked the lime, the more likely is it to be caustic and in good condition. Old lime is in general of little or no value, unless it shall have been hermetically excluded from the air, in which condition it may be kept for any length of time, without losing its causticity.

497. CHLORINE is an element whose power is equally acknowledged in destroying numerous animal and vegetable combinations, though neither it nor lime are to be considered capable of acting on all such matters without exception. This element acts in a very different manner from lime, however, its great tendency being to *dehydrogenate*, or to subvert the combinations of animal and vegetable matter by combining with their hydrogen, and forming the compound termed hydrochloric or muriatic acid. Chlorine gas is evolved from a mixture of muriatic acid and peroxide of manganese, or from a mixture of common salt, sulphuric acid, and peroxide of manganese. Nothing, however, affords it more conveniently than chloride of lime, which, when of good strength, evolves minute quantities of chlorine for a considerable time, and can be made to discharge large quantities, on the addition of sulphuric or muriatic acid.

498. Chlorine should never be evolved in large quantities in apartments that are occupied, as it is one of the most irritating of the gases. Minute quantities, however, escaping from a plate of chloride of lime, with or without the addition of a few drops of acid, are not injurious.

499. In all cases where chlorine and acids are used for the purpose of fumigation, their tendency to corrode and destroy metals should not be forgotten, as considerable injury has occasionally been done where this has not been attended to.

500. Sulphurous acid, produced by burning sulphur, acts in many cases by the suffocating fumes which it produces, and in others by its deoxidating agency.

501. Nitrous and nitric acid vapours, associated with water, are evolved when nitre is thrown into an equal weight, or two-thirds of its weight, of hot sulphuric acid, which may be warmed

in a small cup, resting in sand, placed in an iron-ladle, and held over the fire. The smaller proportion of sulphuric acid gives more nitrous and less nitric acid. The acid may be heated till there is a slight appearance of white fumes on its surface. A greater heat volatilizes the sulphuric acid, and produces excessively irritating and corrosive vapours. The great advantage of the nitrous and nitric fumigation, is, that it can be given in sick apartments, without removing the patients.

502. The most powerful of all fumigating mixture, is formed by boiling a mixture of nitric and muriatic acid, chlorine, nitrous acid, and other compounds being then evolved. Or, the same substances may be disengaged, by throwing a mixture of 60 parts of common salt with 100 of nitre, into 200 of hot sulphuric acid, warmed as mentioned in the preceding paragraph. In these mixtures, an excess of acid is generally employed, that the reaction may proceed quickly. If the acid be hot, the fumes are very strong and penetrating. This mixture is usually applied to cellars that require extensive fumigation, when no one is present. It is not to be considered so desirable as lime-whiting; though very useful for temporary purposes.

503. VINEGAR, though much employed still for fumigating apartments, does not so much decompose impurities in the air as the preceding substances, but rather proves refreshing, in the same manner as eau de Cologne, or other agreeable perfumes. It is still used profusely in some public buildings as a substitute for ventilation. In one of these, which I visited lately in this city (London), it is daily sprinkled on the floor, when the parties present are no longer willing to tolerate the offensive atmosphere which a crowded room, without any efficient ventilation, naturally produces. The great amount of decomposing vegetable matter, from the vinegar which adheres to the floor, adds to the permanent deterioration of the atmosphere, and gives a medicated odour to the air, which may perhaps be rendered agreeable by long habit, but which is certainly not very inviting to a stranger. This substance, accordingly, and numerous others

having a grateful perfume, are not to be considered as purifying air, but rather as disguising bad air by the grateful odour they emit.

504. AMMONIA proves exceedingly refreshing to many constitutions, by combining with and neutralizing the carbonic acid of the air; and even in the lungs, where it enters with the air inspired, it produces, no doubt, a similar effect. The more extensive use of this gaseous alkali promises to be exceedingly useful, in numerous cases where the respiration is affected.

505. Excessive heat is considered desirable, where other remedies are not accessible, and may be produced by burning coke or charcoal in a confined apartment, where there is no danger from fire, and when it is unoccupied. The temperature should be elevated, at least, to 212°; some are satisfied with a less elevation of temperature. Dr Henry showed, it will be remembered, that, some years ago, certain infectious matters are entirely destroyed by a heat not exceeding 212°.

506. Where the respiration of individuals is to be protected from mechanical impurities, and where it is of importance, also, to moderate the temperature of the air as it passes to the lungs, the very elegant instrument invented by Mr Jeffrey (JEFFREY'S RESPIRATOR), will be found exceedingly useful. Many, who were formerly confined at home, very frequently, in particular states of the weather, have been able to walk out freely in weather that would otherwise have proved very injurious, by the very mild and equal temperature this piece of apparatus gives to the air as it is inspired, which absorbs the heat retained by perforated silver-plates from the air discharged by expiration.

507. The purification of air supplied for respiration, has also, on many occasions, been attempted with great success in apartments filled with hot and impure air, by a protecting helmet provided with a dependent proboscis, a sponge with water, and occasionally variable proportions of ammonia or other substances being added to it, according to the nature of the impurity which it may be intended to counteract. Firemen and other adven-

turous individuals, have often proceeded fearlessly, with such helmets, into apartments, where it would have been impossible for them otherwise to have entered.

508. The dependent proboscis enables the inspired air to be taken from the surface of the ground, where it is often comparatively good.

In the same manner, individuals may, by still more extended arrangements, and with the aid of a force-pump conveying air through tubes to any distance, penetrate through atmospheres that would otherwise prove fatal. A modification of the diving apparatus would suit every useful purpose.

509. Lastly, ATMOSPHERIC AIR, freely introduced by good ventilation, must always be considered the most important of all fumigations for ordinary purposes, and a material which is, in general, sufficient to oxidate or burn off, by slow combustion, innumerable impurities that are apt to be developed in stagnant atmospheres, particularly where animal and vegetable matters abound, though, for extreme cases, it has not the power and energy of lime, chlorine, or acids.

2. ARTIFICIAL ATMOSPHERES.

510. The first and most important of all atmospheres that demand attention, after purity of air has been secured, is the atmosphere of equal temperature. This will be attended to under the communication of heat.

511. Though the production of artificial atmospheres has attracted considerable attention from the experiments of Beddoes and Davy, independent of numerous others who have directed their labours to this subject, the communication of moisture and the maintenance of a fixed temperature, appear to have engaged more exclusive attention than might have been anticipated on so important a subject. The temperature and moisture of the air are certainly the most important circumstances that demand attention, after securing air of sufficient purity; but the resources

of chemistry have opened vast fields of improvement as yet uncultivated; or, at least, only on a limited scale, and practised by a few individuals.

512. Now, however, that so many gases and vapours have been discovered, and where the movement of the air can be regulated by a ventilating power capable of precise adjustment, it appears abundantly obvious, that, were more extensive arrangements made for this purpose, particularly in hospitals, a more extended controul might be obtained over the animal economy in many cases of disease, and a series of gaseous remedies brought into powerful operation, through the medium of the lungs, and also by their action on the skin.

513. Medical men have long and justly been jealous of any interference with organs so important in their functions, and so delicate in their structure, as the lungs; but, if a proportionate delicacy and care be employed in the remedies applied, certainly no field holds out a more promising path of inquiry, than that which is presented in investigating the influence of atmospheric air upon the person, and the varied materials that can be mixed with it, and thereby brought to bear more gently and unconsciously upon the system, than by any other mode of treatment.

514. Again, there are various diseases in which the lungs bear a very prominent part, in relieving the body from the noxious products that abound in it, and where the percentage of carbonic acid discharged is considerably beyond the amount evolved in health. Farther, the offensive odour discharged from the lungs and surface of the body, in particular stages of disease, where they do not arise from an incipient putrefaction preceding dissolution, evidently indicate the great importance of allowing every facility to the lungs and skin to operate according to the laws that regulate the diffusion of gases, which have thrown a new light on some of the functions of the animal economy, more particularly those that regulate respiration and transpiration. How important would it be, in such cases, that air, loaded with the products of respiration and transpiration, instead of lingering around the person, and following

a devious and uncertain course, from an ill-defined and dubious ventilation, should pass away continuously in an unceasing stream, and be replaced by a pure atmosphere at a regulated temperature, and in a precise state of dryness or humidity, so that, at one time, the full oxygenating influence of the air should be brought to play upon the body with the highest power of evaporation, or one of these forces be made to act in full while the other is subdued.

515. I certainly am disposed to join with those who consider that the increasing attention now paid to the humoral pathology, is well justified by the facts which the progress of science has evolved, and that, in connexion with those, there are numerous cases where the more full, the more free, and the more highly sustained action of the air, would consume, oxygenate, and burn off from the living frame a large amount of those impurities that are prone to develope or augment disease, exactly in the same manner as air is always tending to oxygenate every external product, where organic structure, under the influence of the laws of life, does not interpose its peculiar functions through those wonderful processes of assimilation that can only be conducted in the exquisite chemical laboratories of the living frame.

516. What frequent repetition of any ordinary prescription can ever approximate to,

20 distinct and separate impulses in	1 minute,
1,200	1 hour,
28,800	24 hours ;

and all these acting, not upon a secondary organ—not subject to any intermixture with the food or products of digestion—but conveyed directly to the blood in the lungs, and presented to an area many times exceeding that of the surface of the body!

517. By constructing a few chambers in every hospital, where the quality of the air that passes the zone of respiration might be entirely under control, and medicated, heated, dried, moistened, cooled, and applied in any quantity, as circumstances might dictate, a more specific power would be obtained, capable of being applied advantageously in numerous cases of disease.

518. As to the varieties of atmosphere that might be applied in this manner, they are exceedingly numerous, particularly if made to include a rapid movement upon the person. A rapid movement of air directed upon the body, and particularly upon the head, refreshes many as much as a breeze upon the top of a mountain, and is grateful and applicable on many occasions, where we cannot resort to water. The following indicate some of the leading atmospheres that might be resorted to, including, in general, materials that have been already used; but not in that precise determinate form in which they could be applied in air-baths expressly constructed for the purpose.

AIR BATHS.

1. Dry Air.
2. Dry and Hot Air.
3. Dry and Cold Air.
4. Rapid and Hot Air.
5. Rapid and Cold Air.
6. Moist Air.
7. Moist and Warm.
8. Moist and Cold.
9. Rapid Moist and Warm.
10. Rapid Moist and Cold.
11. Steamed Air, or Steam Baths.
12. Highly Oxygenating, by an infusion of oxygen.
13. Less Oxygenating, by diluting air with nitrogen.
14. Deoxidating, by adding minute portions of deoxidating agents.
15. Nitrous oxide (Davy's intoxicating gas).
16. Nitrous Acid.
17. Nitric Acid.
18. Chlorinated.
19. Sulphureous.
20. Carbonic.
21. Ammoniacal.
22. Prussic.

23. Acetic.
24. Arsenical.
25. Mercurial.
26. Alcoholic.
27. Etherial.
28. Benzoic.
29. Camphoric.
30. Lavender.
31. Orange.
32. Cinnamon.
33. Creosotic.
34. Hydrosulphate of Ammonia.

519. The facility with which such materials, and numerous others, might be introduced in determinate quantities, will be perfectly familiar to all who have seen the apartments and air-baths which I have constructed for the purposes now mentioned; the materials were introduced, by being conveyed to a ventiduct, which was the sole supply for the atmospheric air used, the chemicals added being communicated by various arrangements, according to their peculiar properties, the quantities required, and the manner in which they were to be used.

520. Experience can alone determine the extent to which such arrangements may prove valuable. I have certainly some confidence in the value of arrangements for determining for some medical purposes a much more rapid movement of air upon the person than has hitherto been used, where a powerful warming, oxygenating, cooling, or evaporating effect is required. And chemicals, though they require to be tried with extreme care and much attention, appear to be capable of being often added with advantage, from the numerous effects I have seen in the laboratory and in manufactories. There are none of the agents mentioned in the preceding list, whose power I have not repeatedly seen acting in various ways, according to their quantities and other circumstances; and I have no hesitation in endeavouring to call a more marked attention to the importance

of their being applied, by gentle diffusion, through the atmosphere, in the manner adverted to.

521. The medicated vapour-baths, and the hot air-baths, afford the nearest approximation to the system I have been adverting to; but they do not appear to have had the powers of controlling and regulating the movements of the air upon the person, for facilitating the removal of noxious products by exhalation and diffusion, to the extent I should consider desirable. The great object is not merely to communicate certain materials to the system, and allow others to evaporate or escape, but also to withdraw these as they are evolved, so rapidly from the vicinity of the person, that they shall not remain and interfere with the evolution or discharge of materials that have yet to be disengaged. Mr Whitelaw's medicated vapour-baths have presented some of the most important and extensive arrangements I have hitherto seen applied to practice. By the arrangements which Dr Lawrie has shewn me at these baths, he has not only the united influence of heat and moisture, but also of various agents derived from the vegetable kingdom, which are made to act through the medium of the steam. The herbs used are collected in America, from the localities where, from the nature of the soil, their true medicinal virtues are found developed in the greatest perfection; they are then dried with great care, so that their volatile and essential oils are preserved as much as possible, and they are used both in the medication of the bath, and also as internal remedies.

522. Besides those atmospheres that may be produced in the hospital or the chamber of the invalid, a very pleasing and refreshing variety may be communicated to ordinary atmospheric air, by causing steam from a small retort to mix with it, after adding a few drops of oil of lavender, oranges, cinnamon, eau de cologne, or of any other volatile material that may be preferred, the whole atmosphere of the apartment being soon impregnated with the volatile matters they communicate to the passing air.

PART III.

ON THE PRODUCTION AND COMMUNICATION OF HEAT AND LIGHT, AND THE PHENOMENA OF COMBUSTION.

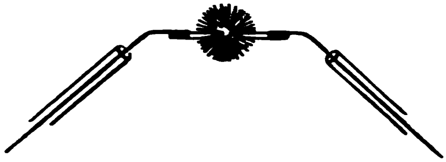
523. These subjects are so intimately associated in numerous practical questions, that some preliminary remarks are necessary, before entering on the individual chapters.

524. The precise nature of Heat and Light is still unknown, though numerous facts attest the very intimate connection that subsists between them, electricity, and magnetism, and give a reasonable presumption in hoping, that the progress of science may one day reveal some new fact bearing on their mutual connection, eventually simplifying the innumerable details that have been ascertained by experiment, and giving man a still more extended power over the material world.

525. The most intense heat and brilliant light hitherto developed by artificial means, and capable of being employed for various experimental purposes, though not sufficiently perfect for ordinary use, is that which is produced by a stream of galvanism proceeding *(in vacuo)* from one piece of charcoal to another, and more or less nearly into contact, according to the power of the galvanic battery employed. The general appearance represented by such an apparatus, is given in the accompanying figure. This light has been repeatedly tried in individual apart-

ments, and lately a very interesting experiment was made with it on a very large scale in the Place de la Concorde at Paris, but

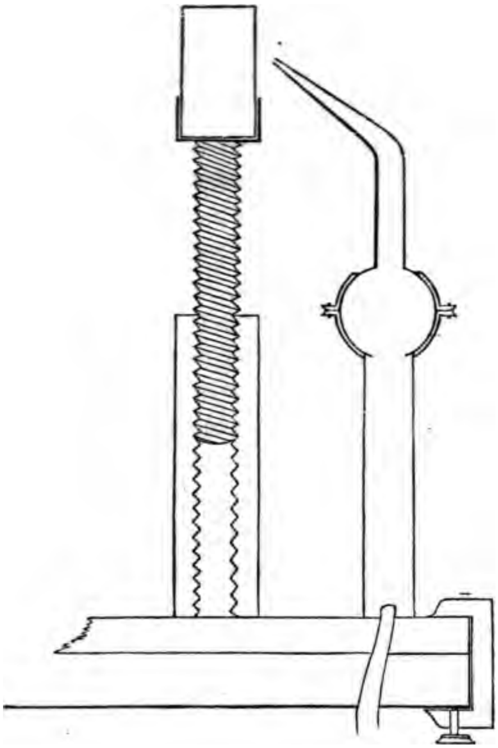
Fig. 141.



hitherto it has not been so economically produced, nor so steadily sustained, as is required for practical purposes.

526. The lime-ball light, introduced by the late Captain

Fig. 142.



Drummond, and also pointed out by Mr Gurney, is deve-

loped, by heating intensely a ball or cylinder of lime, against which a stream of coal or hydrogen gas is directed, its combustion being animated by mingling with it, where it strikes the lime, with proper precautions to prevent accident, a stream of oxygen gas. The lime does not burn, but becomes intensely luminous when heated by the combustion of the mixed gases, and is slowly dissipated in vapour as the operation proceeds, so that it is necessary to renew the balls employed from time to time, or to use a cylinder turned by clock-work, and exposing a new surface continually to the gases.

527. In both the preceding cases, the chemical action of the materials employed is the effective source of the light developed.

528. But for all ordinary practical purposes, carbon, and compounds of carbon and hydrogen, are the great sources of artificial heat and light; and though oxygen, nitrogen, and other substances, may be associated with many of them, still these are not considered to contribute to the development of the light and heat. They tend rather to modify the combustion; the heat and light are developed by the action of the carbon and hydrogen, with the oxygen of the air.

529. Whenever carbon burns freely, and is abundantly supplied with oxygen, it forms carbonic acid gas, whatever its previous state of combination may have been. In respect to this, it may be well to recollect the facts mentioned as to the quantity of air consumed by carbon and hydrogen, as stated in the five following paragraphs. (Fractions are omitted.)

530. Six tons of carbon consume sixteen tons of oxygen, which are found in seventy-two tons of air, producing twenty-two tons of carbonic acid, and disengaging fifty-six tons of nitrogen gas.

531. But if the carbon be supplied with an insufficient quantity of air for the above purpose, only half the quantity of oxygen is consumed, and carbonic oxide gas is formed, a gas which passes off invisibly, unless it shall meet with fresh quantities of air, while still at an elevated temperature; in this case,

it burns with a pale blue flame, attracting as much more oxygen as it may have already gained, and forming ultimately the same product (carbonic acid gas) that would have been formed at first, had it then been freely supplied with air.

532. In general, carbonic acid is formed where the air first gains access to the fire, if the carbon be at a sufficient heat, as in a red-hot cinder fire; and, in passing through the superincumbent cinders, the carbonic acid loses one particle of oxygen, and becomes carbonic oxide gas.

533. The lost oxygen takes a particle of carbon from the cinders, and forms another portion of carbonic oxide gas.

534. Again, when hydrogen burns, it invariably produces water, every ton of hydrogen consuming eight tons of oxygen, which are found in thirty-six of air, producing nine tons of steam or watery vapour, and liberating twenty-eight tons of nitrogen.

535. The combustion of all kinds of ordinary fuel is much affected by the amount of moisture in the air, the hydrogen and oxygen of this moisture acting chemically on the inflammable matter, and producing various inflammable gaseous compounds. In frosty weather the air is dry, and the blue flame of a cinder fire is not diluted by hydrogenous gases, which alter its colour, as there is comparatively little moisture in the air to afford the hydrogen.

CHAPTER I.

MEMORANDA ON THE COMMUNICATION OF HEAT.

536. Heat is communicated from one matter to another, by two very different modes—viz., by Radiation and by Conduction.

537. RADIATION signifies the rapid emission of heat, and its passage from one body to another, in the same manner as rays of heat pass from the sun to the earth. As a little candle is not prevented from shining, though placed in the sunbeams, giving out both light and heat to all surrounding objects, in proportion to the intensity with which it burns, so all substances that are visible at the surface of the globe, at all temperatures, are considered to be continually interchanging rays with each other, the proportion from each necessarily varying indefinitely according to circumstances.

538. Different bodies vary much in their power of radiation; those with rough and porous surfaces radiate well.

539. Bodies that radiate heat well when hot, absorb it quickly when cold; or good radiators are also good absorbers of heat.

540. Polished metals are bad radiators of heat, bad absorbers of radiant heat, but powerful reflectors, throwing back a large portion of any radiant heat that falls upon them.

541. Every individual, according to the state of his circulation, and the temperature of the surface of the body, radiates heat to others, in the same manner as rays of light emanate also

from the living frame, and every other object, and reach the eye; they would not otherwise be visible.

542. UNREQUITED RADIATION signifies the radiation of heat that ensues under circumstances where an inadequate return is received, and this is accordingly followed by a reduction of temperature in the body radiating.

543. In a clear dry night, the ground affords a specimen of unrequited radiation, discharging much of the heat it may have imbibed through the day, and meeting with little or no return. It becomes colder, consequently, than the superincumbent air.

544. A cloud over any place receives radiated heat, but prevents reduction of temperature by returning it.

545. CONDUCTION.—This signifies the slow and direct communication of heat from any warm object to another in actual contact with it. Radiation is the term applied when the communication of heat ensues between substances at greater or less distances from each other. The sun and a common fire give out heat, and warm by radiation. A stove may radiate, but it heats also the air in direct contact with it.

546. Metals are good conductors of heat, taking it rapidly from any object warmer than those with which they may be in contact, and evolving it equally to those that are colder, and in contact with them.

547. Glass, bricks, porous solids, as charcoal, fur, cotton, and wool, are bad conductors of heat.

548. Bad conductors are used for surrounding materials to be kept warm or cold, that heat may not escape from them, nor enter to them.

549. The most powerful combination for giving or acquiring heat is formed where the material is composed of metal, that the conductors may be good, and the surface non-metallic, but porous, soft, or painted, that the absorption or radiation may be powerful.

550. Again, in the most perfect arrangement for retaining heat, the substance should be made of a non-conducting mate-

rial, and the surface of a brilliantly polished film of metal, that it may neither conduct nor radiate well, but be powerful in reflecting.

551. Clothing of different kinds is more or less warm to the feelings solely by preventing the cooling influence of the external atmosphere; and in climates, such as this country presents, a warm porous clothing, powerful as a non-conductor, but no barrier to the diffusive action of the skin by exhalation, is the great desideratum. Woollen stuffs afford this in perfection; and the value of flannels, in reference to the general health, cannot be too much appreciated, especially where, from the nature of the occupation, the excitement or other causes, the circulation is subject to considerable inequalities of action.

552. The finer kinds of woollen clothing are often very imperfectly porous, and not therefore so conducive to health. Among other materials, numerous cases occurred, when the Mackintosh was manufactured in a less open form than is now given to it, where the health was injured by its constant use. All clothing which is close in its texture, or in the form in which it is applied to the body, so that the natural exhalation does not escape readily, but becomes prone to render it damp by condensation in cold weather, should be considered defective.

553. Were the amount and quality of clothing more frequently adapted in this country to the state of the atmosphere to be encountered, whether at home, in the open air, in churches, or in assemblies, innumerable cases of disease would be prevented.

554. The force of physiological representations appear gradually to be dissipating the folly and the pernicious consequences that have too often regulated dress in society; but the field of improvement is not yet exhausted, and a little more attention to the functions of the living frame in connexion with this subject cannot be too much appreciated. The great point should be to protect the person from sudden transitions of temperature, and those local currents that still abound in ordinary habitations, as well as to sustain an agreeable but not an oppressive warmth.

555. Among those engaged in special pursuits, where parti-

cular clothing is required from the circumstances under which they are exposed, the porosity of the clothing cannot be too specially studied. A soldier encased in a metallic helmet, in a cuirass, and the rest of his body in leather, every pore of which is obstructed, affords a good example where the diffusion of the skin is retarded, in an extreme degree, and increased duties thrown on the lungs and face, the latter often appearing suffused with perspiration, at times when, with a more porous dress, nothing of the kind would be observed.

556. One of the reasons why sleep is so refreshing in an ordinary bed, compared with what it is when the day-clothes are not taken off, is the great comparative freedom with which the function of exhalation goes on.

557. In many places, both abroad and at home, the clothing of the feet appears to require much attention. In a military hospital abroad, almost all the men appeared to me to have diseased feet, in addition to the other complaints for which they had entered. The foot is too often treated as a block of wood, not as a part of the living frame; the high-heeled and narrow-pointed shoes of former days may have disappeared, but the air-tight boot cannot be recommended for all constitutions. The Royal College of Surgeons of Edinburgh have done well to place a human foot, shewing its exquisite structure, and the wonderful reticulation of bloodvessels which it presents, in one of the most conspicuous places of their Museum. No one can look at it for a moment, without seeing how incompatible the functions of these vessels must be, with the tight press into which they are so often screwed. Some years ago, in a short notice I made on this subject, at the Society of Arts of Edinburgh, I shewed a Bohemian shoe or clog, divided into two parts, but connected by a chain which gave sufficient elasticity to admit of the natural motions of the foot; and having left it with Mr Dowie, he afterwards made his improved India-rubber shoe, which has attracted so much attention, and been so largely used, and to whose very excellent and interesting papers on the Shoe, and on the Human Foot, I must refer for further information on this subject.

CHAPTER II.

THE OPEN FIRE.

558. Few circumstances, perhaps, have tended so much, in modern times, to alter the state of health as affected by the internal arrangements of dwelling-houses, as the great reduction in the altitude of the chimney-piece, and the more skilful disposition of the fire-place for the economy of fuel. The practical consequence has been, that a less amount of air is necessarily forced through individual apartments, when the coldness of the weather renders it necessary to keep the windows shut; and, above all, that the air which does pass to the fire, is, in general, below the level of the head, and exercises, accordingly, little or no purifying influence upon that portion of the atmosphere which is within the zone of respiration.

559. The cottage-grate, so very generally introduced of late years, is extremely comfortable from the low position of the fuel, the comparative absence of iron, and the powerful radiating influence of the fire-bricks that form the back and sides; but the smaller the apartment, and the more perfect its construction, the less must it alone be trusted to in securing ventilation.

560. A common fire heats an apartment, in general, almost solely by radiation, excepting the influence of the flue upon the wall. In some few cases, fire-places have been constructed so as to partake in part of the character of stoves.

561. The peculiar advantages of a fire-place are not merely its power of warming an apartment, the circulation of air which it induces, its accessibility, and the influence of the light which it evolves; but the very grateful effect which it produces after the body has been chilled by any special cause, whether in door,

nt of doors, stimulating it, and exciting the circulation to greatest degree which may be considered agreeable, and per-ting each individual to adjust the distance which is most suit-e to his own constitution, and the previous exposure to which may have been more immediately subject. The light, also, not to be considered a mere nominal advantage, but a real and sitive benefit, affecting the whole system by its physical action, dependently of the cheerful impression which its liveliness is lculated to excite, and which, to many, is so engaging, that hey feel as if they were not alone when they have the company f a glowing fire. These considerations will probably always ustain the open fire-place, in countries where fuel can be pro-cured with sufficient economy; but its disadvantages, in other respects, compared with the stove, are marked, particularly its expense, its local action, the dust it is apt to produce, and the frequent attendance which it requires.

The great points that require attention in the common fire, are—

I. Depth of Fuel, from top to bottom, and—

II. Breadth from side to side, to give an ample radiating surface.

III. A Blower, to close the ingress of air above the fire, that it may kindle quickly, and burn powerfully when necessary.

IV. A Valve or damper, to reduce the draught when the com-bustion is too rapid.

V. A Front, made of the lightest possible iron-bars that may be considered lasting, and placed on the level of the floor, that the floor and feet may have the fullest benefit from the radiation. Placed at a higher position, it has, in some respects, the advantage of throwing the heat in a different manner, but it never then affords the personal comfort which a low fire presents to those who may wish to be sensible of the influence of its rays,—a practice which, although not to be recommended to pass into a habit, is too agreeable not to be resorted to when the system has been chilled. It is not, in general, sufficiently remembered that the great object, with all ordinary fires, is to heat the floor. If this

be accomplished, it moderates the severity of cold air there, and the upper portion of the apartment is warmed by the ascending currents that are immediately developed.

VI. An ash-pit, with means for preventing the ingress of air below the fuel. Air should enter in front alone; the radiation is then powerful in front, and strikes forward. In many fires the radiation is most powerful below, and strikes downwards, where it is of no value.

562. Where iron is used in large quantity around an open fire, it robs so much heat from it, and communicates so large a quantity, by conduction, to the current of air passing up the chimney, that it rarely burns brilliantly. Every portion of metal that may in any way be dispensed with, proves advantageous in an open fire.

563. The following figures illustrate the arrangements of the coke-fire places which I have used for a considerable time, and which have been introduced in many places in this country.

Fig. 143 (No. 1 of this set) shews the general appearance of this fire-place; *b*, the blower; *x*, a section of the ash-pit below the elevation of the fire-place; *d*, *e*, the handles of the valve and of the blower.

Fig. 144 (No. 2). A plan shewing the fire-grate *a*, and the extent of the ash-pit *x*.

Fig. 145 (No. 3). A section of Fig. 143.

Fig. 146 (No. 4). Another view, the front plates and handles for working the valves and the blower being removed, that the manner in which they are attached may be seen; *c*, the counterpoise for the blower. All these parts connected with the movement of the valve or of the blower should be made of great strength, so as not to give way from any ordinary force, otherwise they give no satisfaction.

Fig. 147 (No. 5); plan shewing the arrangements at the level of the damper.

Fig. 148 (No. 6) is a view of the arrangements of *e* on a

larger scale; *g*, a pin which is drawn out of its place by pulling *e* forward; the valve in the chimney can then be set to any

Fig. 143.

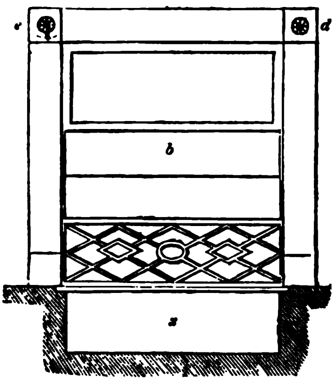
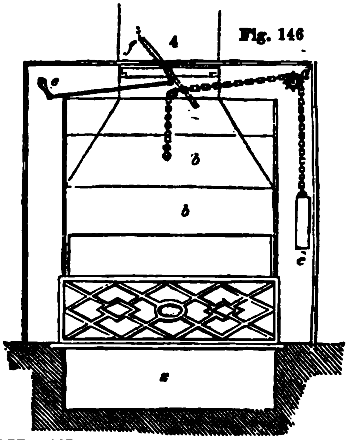


Fig. 146



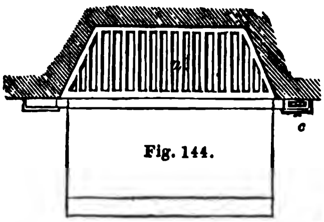


Fig. 144.

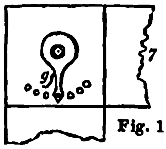


Fig. 149.

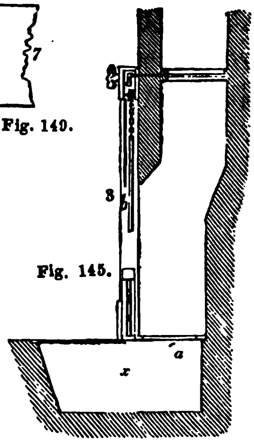


Fig. 145.

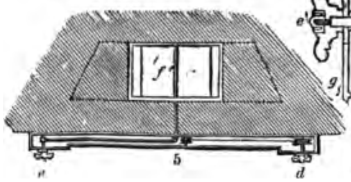


Fig. 147.

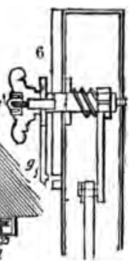


Fig. 148.

position, after which, on letting go *e*, the spiral spring returns it to its proper place, and the pin *g* having been adjusted to one of the openings in which it can be fixed, secures the valve in the position in which it has been placed, the fire burning more or less briskly, according to the amount of air permitted to pass.

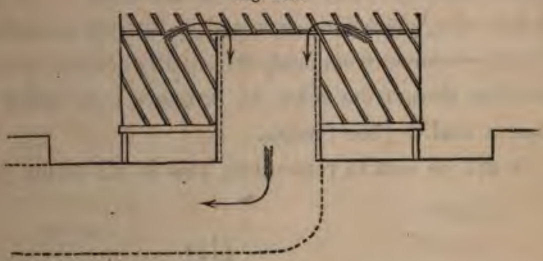
Fig. 149 (No. 7) illustrates the position of the various open-
nto which the pin may be fixed.

564. In open fire-places with descending flues or chimnies, it is always necessary, in the first instance, to determine the descent of the air from the fire-place, by warming the chimney to which it ultimately proceeds, should there be no powerful draught already established there, either by a fire kindled in it, or some other means.

565. Figs 150 and 151 give a view and section of a large fire-place, three feet in diameter, which I constructed in the centre of my practical class-room in Edinburgh. It was always worked with a soft burnt coke, as the flame from coal produced

Fig. 150.

Fig. 151.



smoke which was apt at times to escape from the sphere of the chimney. The interior circle of the chimney was built with very small circular bricks, made of fire-clay, and is not seen when the fire is in full action, being covered by a wreath of blue flame, produced by the combustion of carbonic oxide gas, carbonic acid and nitrogen passing down the centre along with a portion of the air.

566. Those who are accustomed to the use of coke in ordinary fire-places, constructed as shewn in Fig. 143, are never

found again to resort to the use of common coal, as it gives a cheerful and agreeable warmth, while it has the great advantage of producing no soot, and therefore requiring no chimney sweeping. The coke used for this purpose should be in small pieces, not larger than a walnut, soft burnt, that it may kindle easily, and not deprived of the last portions of gas that can be abstracted from it. Hard burned coke, which is difficult of accension, except in furnaces, and prone to go out again, is unfit for an open fire. Some kinds of anthracite do well, others are too difficult of combustion, unless placed on an earthen floor; a grate is not required where little or no ashes are left from anthracite.

567. Many object to the use of coke, in consequence of the fumes or bad air which they suppose to be peculiar to it. This is a mere prejudice, which has arisen from coke having been employed in grates or fire-places not adapted for it. Every coal-fire becomes a coke-fire, as the gases are expelled. It is quite true, that the products of the combustion of coke are very pernicious, and do not produce that visible smoke which is evolved from common coal, and which therefore is, in general, more quickly recognised and corrected. But the products from a cinder fire, produced from coal, are equally noxious, and of the same nature as those from coke, all ordinary coke being formed from common coal. (See Smoke.)

568. It will be well to remember, that in all rooms provided

Fig. 152.

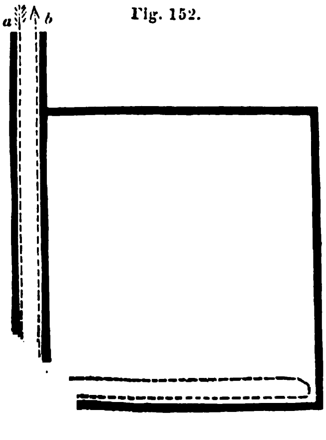
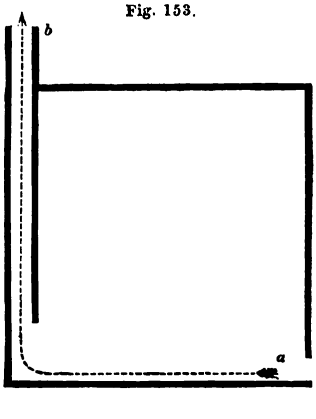


Fig. 153.



with air-tight doors and windows, there is still a tendency to a movement up the chimney, which is supplied by the unavoidable leakage at doors and windows, and that when this is not steady and determinate, a movement often ensues in the manner shewn in Fig. 152. Further, when a fire is kindled, cold air usually flows along the floor from it to the fire, Fig. 153. See Movements in Air, Elementary Illustrations (Supply of Air to Fireplaces).

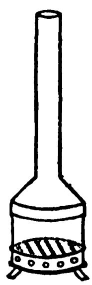
CHAPTER III.

THE STOVE.

569. THE Stove forms a very different atmosphere from the open fire, in so far as it not only radiates according to its temperature, but also communicates heat by conduction (by contact) to the air; and hence, if the surface be contaminated with any oily or other offensive substance, or if it be at such an elevated temperature as to decompose the innumerable particles that float in dry weather in any ordinary atmosphere, it is prone to produce an offensive odour. It also occasionally removes a portion of oxygen from the air, the amount of which is too trifling to be noticed particularly, except in so far as it may act upon matters suspended in the air,—the quantity consumed by the oxidation of the iron is altogether trifling.

570. A chauffer (Fig. 154) supplied with coke, coal, or charcoal, with a door for fuel and a tube attached to it, that the products of combustion may be directly withdrawn, affords the most simple form of a stove. But stoves are made of a variety of materials, of which iron, porcelain, brick, and other species of earthenware, are the most common. The following are the most important circumstances demanding attention in reference to the use of stoves.

Fig. 154.



571. The HIGH TEMPERATURE STOVE is heated to various intensities, from a few degrees above the temperature of boiling water to a red heat. It has all the disadvantages referred to in paragraph 577, in a greater and greater

degree, as the temperature is higher. The principal peculiarity that recommends it, is its great heating power; not the quality of the warm air which it produces. If this stove be used in the apartment in which it is placed, its form is comparatively indifferent. If placed in a cellar, or in any place under the apartment to be warmed, a chamber is usually formed around it, so that the warm air which passes from it may be conveyed where it is desired. See the diagram of the common cockle.

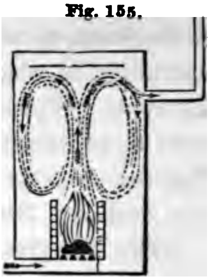
572. The great tendency of hot air from stoves, and of all currents of hot air, is to ascend to the ceiling of the apartment in which they are evolved, so that innumerable instances occur where the heat may be oppressive above, while, at the level of the floor, the air is comparatively cold. Hence all stoves are better when placed below the apartment to be warmed than in it, where local circumstances admit of this arrangement.

573. The larger the surface of the stove, and the less elevated the temperature, the less is the disposition of the warm air to accumulate above.

574. The Low Temperature Stove.—Among the innumerable stoves that have been described of late years, none deserves so much attention as the Arnott Stove, a low temperature stove that combines extreme economy of fuel with great facility of attendance, by those who take the trouble to make themselves familiar with the proper mode of constructing and using it. I have used several in my class-room, as illustrative of this method of heating, and found them to work well. In cases where the nature of the chimney has not been properly adapted to the stove; or where it has been attempted to economise the fuel to an extreme degree, so that the products of combustion were cooled too much and lost their ascensional power; or where the apartment in which it was placed was subjected to the exhausting influence of a passage or adjoining room drawing air powerfully from it,—then it is necessarily prone to smoke in the same manner as an ordinary fire, but in a greater degree, from the more feeble ascending power of the current proceeding from it. This tendency has been counteracted greatly by the adap-

tation of a very ingenious valve, for a description of which and the various details explained by Dr Arnott, I must refer to the work he has published. Fig. 155 shews one of the simplest forms of the Arnott stove. The value of the Arnott stove would have been still more widely appreciated, had it not been frequently made in a manner not recommended by the inventor. I add two remarks in reference to the working of this stove.

Fig. 155.



575. I. The security of the discharge of the products of combustion should be facilitated in all cases where the chimney does not readily and at all times discharge them by allowing the combustion to proceed more freely than where an excellent chimney draught is given. In extreme cases, where no regular chimney could be obtained, and where the draught was sometimes indifferent, by connecting an ingress tube for fresh air with the fire-place, and leading it through the walls in the same manner as the chimney, all return of bad air is prevented, as in this case the extremity of the fresh air-tube, like the extremity of the chimney, has no connection with the apartment containing the stove. The air may pass out or in, up or down, in the aperture referred to, but being without, it is a matter of no consequence.

576. II. The extreme economy of such stoves, arises from two causes,—the large amount of heat which is detained by the stove, and the comparatively small quantity of air which is removed by combustion. Hence, then, this stove is not brought forward as a stove that will ventilate rooms like an ordinary fire, and the ventilation of the apartment must be attended to independently.

577. The PORCELAIN STOVE.—While there are numerous stoves to be met with abroad of the very worst description, there are others of a very superior quality, and, perhaps, as perfect as it is possible to procure. These may be seen in Sweden, Russia, Germany, France, and other countries. The annexed figures represent a form of stove which I saw used at Stockholm, by

Professor Berzelius, and at Berlin, by Professor Mitscherlich, and which has become very common on the continent. Fig. 156 shews the general appearance of these stoves, which are commonly

Fig. 158.

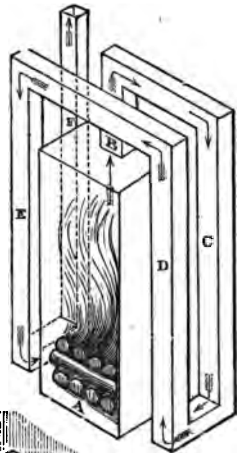


Fig. 156.

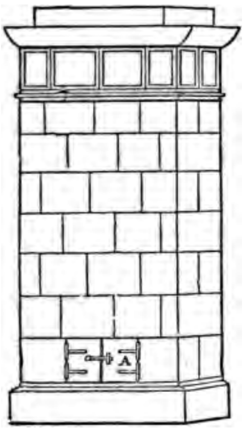
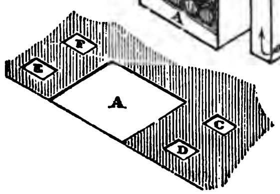


Fig. 157.



ten or twelve feet high. Fig. 157 shews the fire-place, and Fig. 158 indicates the turns made by the flues; latterly, all angles have been removed, and the turns made circular. Dr Ure, in his evidence before the late committee of the House of Commons, on smoke, says that he is sure if I "had ever experienced the effect of the stove-heated rooms of Russia, Sweden, or Germany, I would deprecate their imitation in this country, as the greatest of evils." I must tell Dr Ure, that I have personally examined the arrangements to which I refer in my evidence, and that I consider that I have as good reason to recommend those stoves to which I adverted, as I have to deprecate the others to which I have referred in the first lines in this paragraph. I know none which produce a more mild, genial, and equal temperature. There are few chemists who would not be satisfied that

CHAPTER IV.

STEAM APPARATUS.

579. The principal peculiarities which steam presents, compared with any of the preceding modes of communicating heat, is the facility with which steam apparatus can be sustained at a uniform temperature, the endless variety of forms into which it can be fashioned, the security which it affords against the possible introduction of smoke, as the fire-place may be entirely separated from the stream of warm air upon which it is made to act, and the distance to which steam can be conveyed from the boiler in which it is produced. With steam apparatus, there is not the same extent of power of adjustment, such as is observed in hot water apparatus; but it is, perhaps, more economical in construction where it has to be conveyed to a considerable distance; and, when fitted up in a chamber, from which warm air is to be drawn as it is required, and mixed with cold air before it is used, perhaps there is no better mode of applying heat.

580. Steam-pipes often produce considerable noise when the steam is not sustained in sufficient quantity to prevent occasional condensation, the formation of a vacuum within the apparatus being accompanied with the noise produced by the sudden movements of steam or water within it.

581. So far as I have seen, in large public buildings heated by steam-pipes not placed in a reservoir below, but extending through the building, the result is not so satisfactory as with hot water apparatus, as the steam must either be in full action, or not in action at all, whereas warm water may be maintained at any temperature below 212° that may be required. In other respects, steam apparatus may be generally disposed in the same manner as hot water apparatus.

CHAPTER V.

HOT-WATER APPARATUS.

582. Hot water presents certainly one of the most interesting applications of science to the means for the communication of heat. This mode of warming was invented and applied during the last century in France. About twenty-five years ago, it was systematized and very strongly advocated in this country by the Marquis of Chabannes, who evidently clearly understood its mode of action, and whose description at that period, very distinctly points out its leading advantages. He stated, in a small pamphlet which he published,—

" There cannot be a more perfect idea of the whole operation of the new patent water calorifere, than by comparing its boiler to the human heart, and the tubes through which the water passes to the bloodvessels in the human body. In the water caloriferes, the water is in constant movement as the blood in the veins ; it goes out of it by an upper tube, as the blood by a valve in the heart. It circulates through the house, ascends or descends at will, and returns into the boiler at the bottom to charge itself again with fresh caloric, as the blood ascends, descends, and passes again into the lungs to regain a new portion of oxygen, and recommence constantly the same function of carrying heat to the extremity of the body.

" The fire-place is surrounded by a boiler, from the top of which an ascending pipe leads to a reservoir (which is filled with water), and placed at the upper part of a house, or any where above the said boiler, and from which a descending pipe communicates underneath the boiler, which may be carried in any m; the rarefaction thus produced by the heat in the

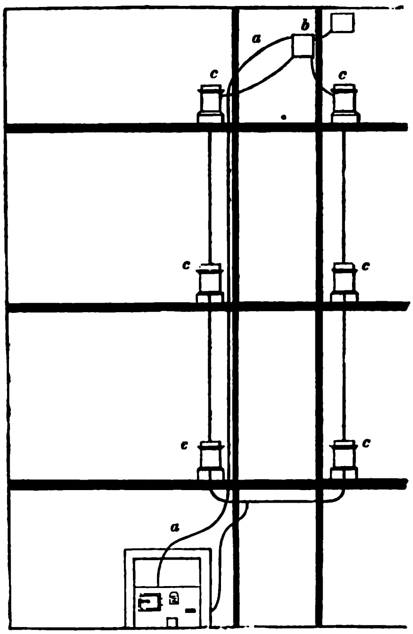
ascending pipe, occasions a pressure from the colder water in the descending pipe, which establishes a perpetual circulation, and, by this means, performs the object of carrying the caloric, wherever it may be desired.

"This new stove is particularly recommended to all those who are prejudiced against the use of air heated in metal tubes in contact with fire. The air can thus never receive above 160 or 180 degrees of heat, nor be in any way decomposed in tubes which are heated by immersion in hot water; while the pleasing effect of a soft and regular heat is constantly felt. The improvement may be added to all present stoves, so that one fire will suffice to warm, at least, four rooms at the same time. The expense of fixing the apparatus is small, when the economy in fuel, by heating so many rooms from a small fire, is considered; besides the advantages of having hot water in every apartment, and getting rid of the dust of a fire in a bedroom, &c. The same fire may also heat a bath. Any kitchen fire to which the apparatus is attached, may warm the staircases, parlours, shops, ware-rooms, &c.,—in short, any number of places, according to the size of the fire, which will, at the same time, supply hot water for all culinary purposes, the scullery, wash-houses, &c. Conservatories, hot-houses, and hot-beds, have been heated upon this principle with the greatest success; and a further advantage in the water caloriferes is, that according to the situation, the heat may be given either above or below the fire. The method of heating by a circulation of hot water, is preferable to steam in many respects; steam requires a strong fire, and to be always kept up, whereas very little fire is sufficient to keep up the heat in the water when once boiling, and to renew the caloric, which is continually passing through the different apparatus for spreading the heat; it is therefore much more economical."

583. The accompanying figure, 159, forms one of the illustrations which he gave. It indicates the fire-place below, and the flow-pipe *a* passing to the warm-water box *b*, and supply-

ing all the caloriferes *c c c c c c*, the water returning ultimately to the boiler, that it might be again heated, and again follow

Fig. 159.



the same course in endless circles, so long as it received heat in the boiler, and lost it in the apartments which it warmed.

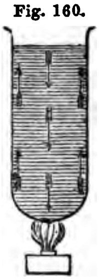
584. The hot-water apparatus does not appear to have made any very marked progress as a valuable practical application, till it was introduced by Mr Atkinson in conjunction with Mr Barrow, of Messrs Barrow and Turner, by whom the hot-water apparatus was prepared that is used in the present Houses of Parliament, and whose experience and extensive practice necessarily advanced greatly the general introduction of hot-water ~~apparatus.

~~. To understand generally the manner in which hot-water acts, it may be sufficient to state, that as the cold water r regions sinks to the bottom of the ocean, and travels

in an under current towards the equator, while the warm water on the surface proceeds towards the poles; so, in the same manner, making allowance for special movements that take place at a temperature below 40° in fresh water, when its ordinary movements are reversed from peculiarities connected with its expansion, *cold or less warm, and consequently heavier water, always descends, and pushes upwards warmer, and therefore, specifically lighter water.* The following figures explain illustrations of the movements of water, which are often shewn by currents of water partly coloured, this portion, on the application of heat, indicating the direction in which the currents proceed, till a uniform tint pervades the whole.

586. A jar of water being heated, as represented in Fig. 160, if the bottom of the sides be well heated, the water ascends on the side all round, and descends in the centre.

Fig. 160.



587. Fig. 161 represents a tube with coloured litmus water below, and common water above. A lamp applied above heats and evaporates the water there, and no farther change is observed. But if the lamp be applied below, then the cold water there being expanded, the colder colourless water descends be-

Fig. 161.

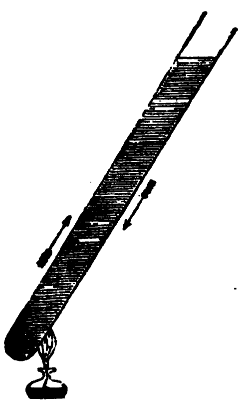
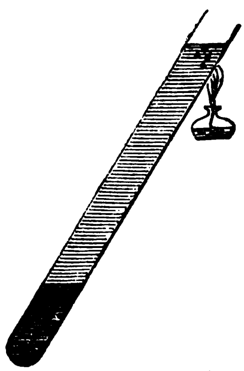


Fig. 162.

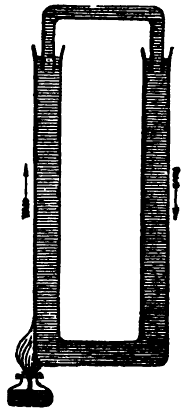


low it, and pushes it up. In this manner, a continuous circu-

lation is maintained, till, from the constant mixture of the ascending and descending currents, a uniform heat is observed.

588. Fig. 163 indicates a tubular glass apparatus, well adapted for shewing the manner in which hot-water apparatus operates, water being placed in one limb and coloured water in the other. The fluid moves upwards in the limb to which the heat is applied, descending in the opposite limb.

Fig. 163.



589. Figs. 164 and 165, taken from the Gardners' Magazine, illustrate the first arrangements made in this country in the preliminary experiments designed for heating hot-houses by hot water, upwards of twenty years ago, and to which I have already adverted, in mentioning Mr Atkinson and Mr Barrow, of Messrs Barrow and Turner.

Fig. 164.

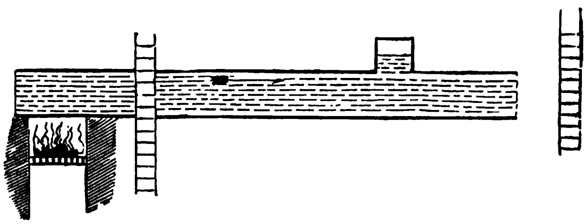
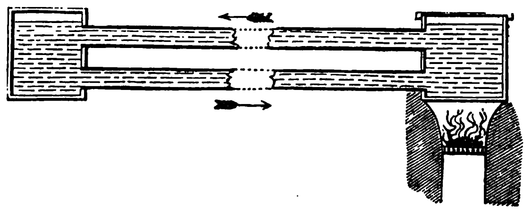


Fig. 165.



590. Figs. 166 and 167 indicate the circulation of water in a bath heated by the action of a fire upon a large elbow A, water in it communicating freely with the water in the

bath B, both above and below. This form is extremely simple and effectual, the rapidity of the heating of the bath being de-

Fig. 166.

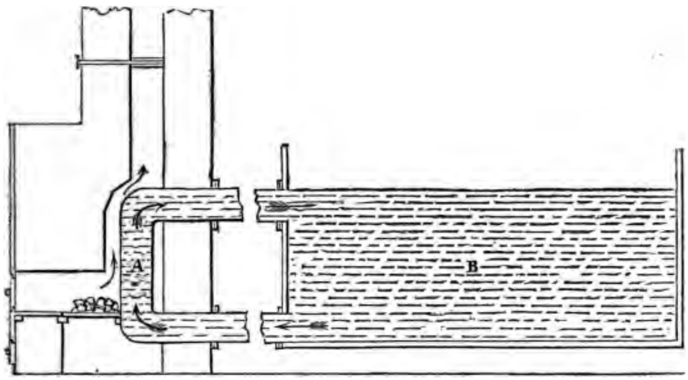
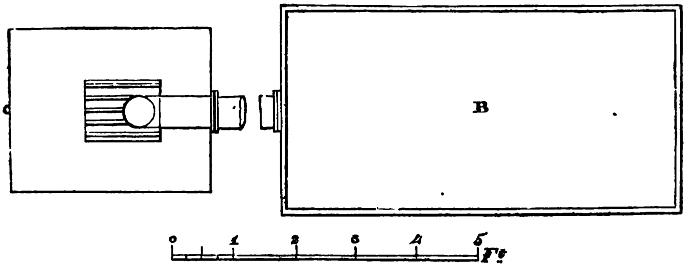


Fig. 167.

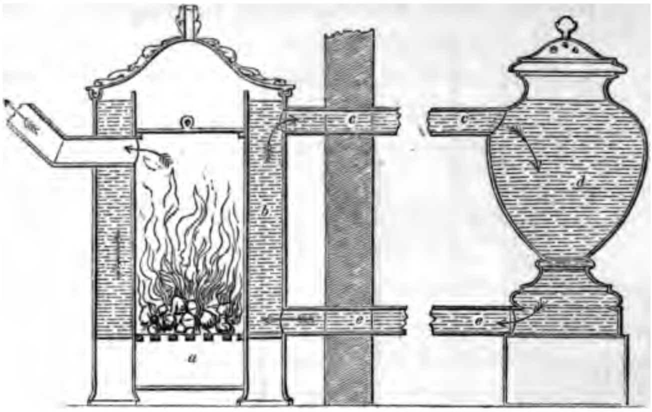


pendent on the size of the elbow and the amount of fire which can be brought to play upon it. Where more rapid heating, and the power of subsequently warming and cooling the bath are required, more complicated arrangements are necessary.

591. Fig. 168 shews an internal fire-place communicating with an extensive range of pipes and pedestals, one of which only is represented. When cold water is freely supplied from a large range of apparatus, a large fire may be freely applied to the boiler. This form of fire is more effective than that shewn in the preceding case, in proportion to the amount of fuel used;

but the simplicity of the iron apparatus in Fig. 162 renders baths more accessible in many cases where fuel is economical,

Fig. 168.



and where more complicated apparatus is not readily obtained. The two covers above the smoke-flue are moveable.

592. The arrangements adopted in some drying-houses shew a very effective form of applying hot water apparatus, and one which it may be always desirable to keep in view, though the extent of diffusion given for such purposes is necessarily far beyond that required in ordinary apartments, and does not admit of that amount of control which is desirable where it is necessary to provide for rapid fluctuations of temperature, and great changes in the numbers attending. The section and plan, Figs. 169 and 170, indicate the progress of the air from the external atmosphere to the warming chamber; from it the air passes through the drying-room, the rapidity of its flow being gulated by a valve, placed in the dis-ring tube, communicating with the ex- air.

Fig. 169.

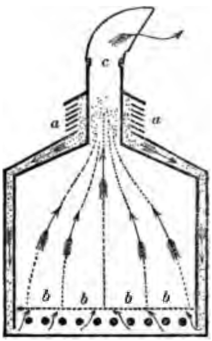
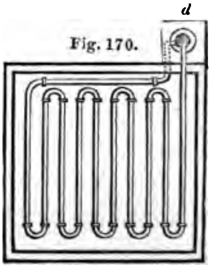
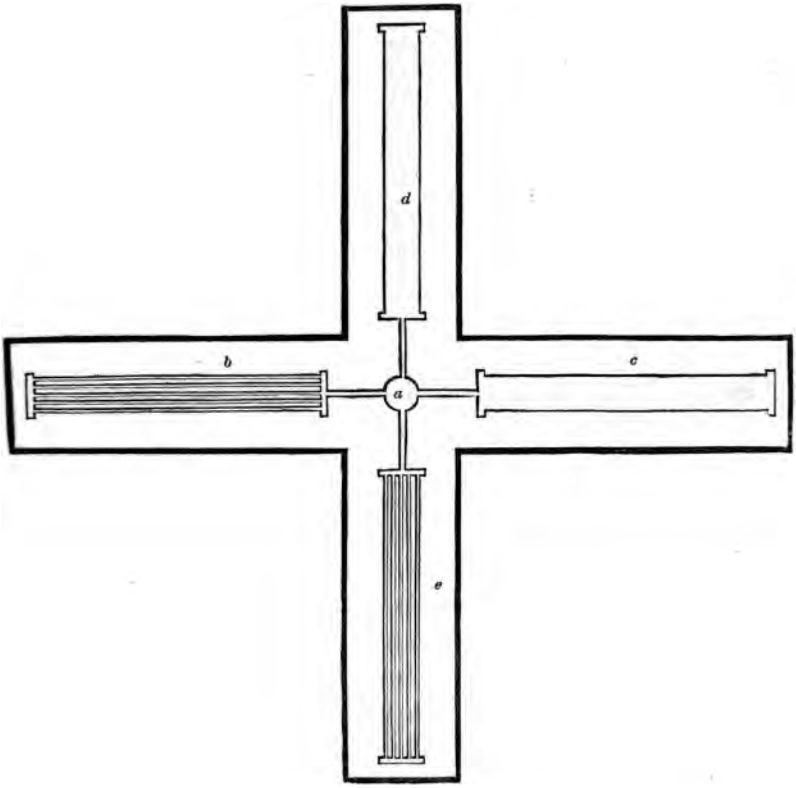


Fig. 170.



593. The most desirable arrangement of hot-water apparatus, in many large establishments where the apartments are not liable to be crowded, consists in providing a central warm water reservoir *a*, Fig. 171, from which the whole building can be heated,

Fig. 171.



the warm surface being expanded where great equality of temperature is necessary throughout the whole basement, as in *b*, *c*, *d*, and *e*. The warm water passes from a boiler to *a*, proceeding then to *b*, *c*, *d*, and *e*, and returning ultimately at a lower level to the boiler ; *c* and *d* are supposed to be finished in the same manner as *b* and *e*.

594. But in all cases where it is necessary to have the power of providing, on the shortest notice, air at any required tempera-

ture, a hot-air chamber, from which hot air can be procured to the extent required, and a mixing chamber, in which it can be tempered with cold air, are essentially necessary. For this purpose, any form of hot apparatus, such as is represented in Fig. 172 (a plan), or 173 (a section), may be used; *b* indicates

Fig. 172.

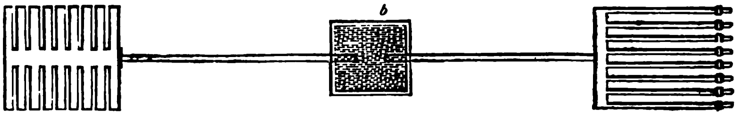
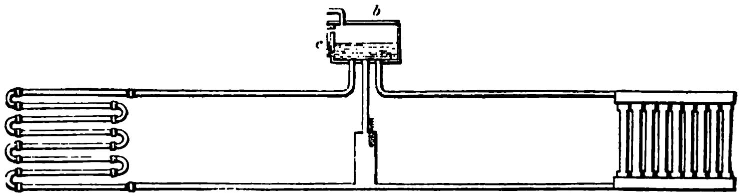
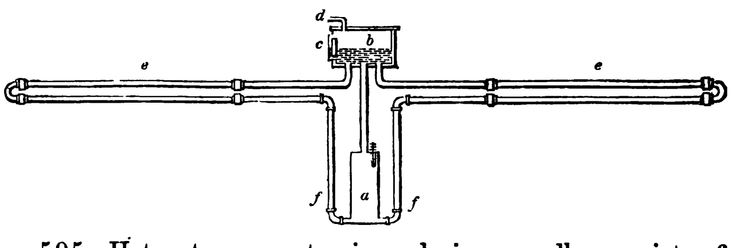


Fig. 173.



the hot-water in both, supplied from the boiler, and communicating with the apparatus on either side; *c*, a glass tube shewing the height of water in the reservoir; the waste vapour-pipe above is usually led into the chimney. In all such cases the water may be led into an indefinite number of coils or boxes from the expansion-box, the circulation being always maintained from *a* to *b*, from *b* to *e*, and from *e* to *a* by *f*, as indicated generally by Fig. 174.

Fig. 174.



595. Hot-water apparatus is made in an endless variety of forms according to the purpose to which it is to be applied, and the circumstances under which it has to be constructed. In Fig. 175, *a* represents the boiler, *b* the flow-pipe, *c* the pipe for the

return of hot water, after losing part of its heat in communicating the temperature required, *d* the feed-pipe, supplying any loss

Fig. 175.

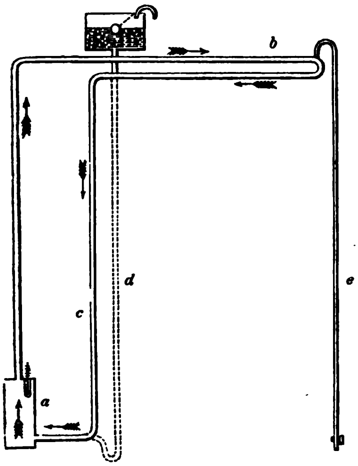
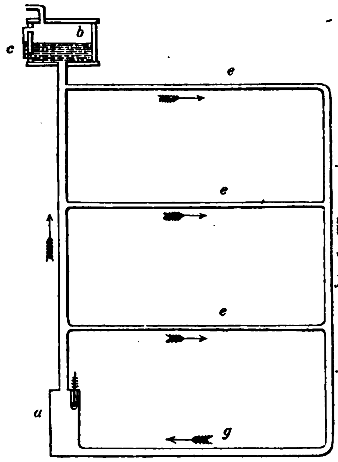


Fig. 176.



of water from a cold-water cistern, *e* a smaller tube by which any air accumulating in the upper tube, and impeding the circulation, may be discharged. In Fig. 176, *a* indicates the boiler, *b* a hot-water reservoir, in which any air expelled from the water is collected, *c* the glass-gage, *e*, *e*, *e*, lateral communications for heating different floors, *f*, *f*, the descending or returning branch, terminating in *g*, by which the lower floor is heated.

596. The preceding figures indicate the more common varieties of hot-water apparatus in use. A thermometer placed in mercury contained in an iron-tube, penetrating into the hot water, should be attached to the boiler, that the temperature may be regulated. The less the elevation to which the temperature of the water may be carried, the less is the apparatus prone to leakage; the more concentrated the mass of the apparatus in any chamber, the more easily is it inspected; the more extended the distribution of the hot-water apparatus, the more equal is its action, and the greater the facility with which an equality of temperature can be sustained, excepting the cases mentioned in paragraph 594. Local circumstances should be studied minutely in

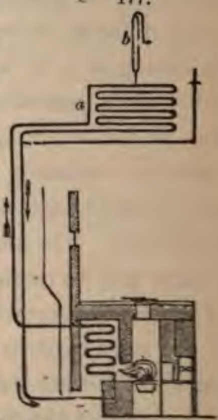
every case before any preference is given either to the aggregated or extended forms of apparatus which have been represented.

597. As to the form of boiler, none appears to present so many advantages as the Cornish boiler, in which the fire is surrounded on every side by the hot-water apparatus. The more simple figure, introduced in many of the preceding illustrations, has been given solely that the diagrams might be rendered plain, and explanatory of the circulation of the currents.

High Temperature Hot-Water Apparatus.

598. Besides the ordinary mild hot-water apparatus, another kind has been introduced by Mr Perkins, which has peculiar advantages and disadvantages. The great peculiarity of this apparatus is the circumstance, that though provision is made for the expansion of the water when it is heated, it has no free communication with the external atmosphere; and being enclosed accordingly in air-tight tubes, it can be elevated to a temperature far beyond that of boiling water. Hence it can communicate a higher temperature, in proportion to its surface, than mild hot-water apparatus; it can be introduced conveniently where larger apparatus is not applicable; and, when the coils of this apparatus are covered by a metallic casing, having a more extensive surface than they present, any reduced temperature may be obtained from them that may be required. The arrows in the accompanying Fig. 177, indicate the progress of hot water from the coils in the furnace, to any coil, *a*, intended to heat the room in which it is placed; *b* is the expansion tube. On the other hand, if the tubes in this apparatus be used at the high temperatures which they can command, air coming directly in contact with them acquires the same peculiarities that are observed when it touches very hot iron-stoves at similar tempera-

177.



'es. This variety of apparatus should be carefully distin-.shed from the mild hot-water apparatus prepared by Mr rkins, with tubes of a similar size. A very ingenious ar-ıgement has lately been introduced by Mr Perkins, for facili-;ing the junction of cast-iron pipes used for mild hot-water paratus, which are connected, at once, according to his plan, being made to screw upon each other.

CHAPTER VI.

VENTILATION OF OIL-LAMPS, CANDLES, AND GAS-LAMPS.

599. In the flame of candles, oil-lamps, and gas-lamps, the principal part of the light developed, arises from solid carbon (charcoal) at a white heat, which is separated from the inflammable matter by the heat of the portion previously consumed, and temporarily suspended in an exquisitely minute state of division. This carbon proceeds more immediately from gas or vapour. When gas is not employed in the first instance, the production of gas or vapour always precedes the separation of carbon. A candle or oil-lamp is not kindled till gas or vapour, produced by the heat applied, starts out from the inflammable matter. The continued production of gas or vapour is sustained by the heat of combustion. Every successive portion of gas and carbon, as it burns, produces the necessary intensity of heat for the illumination and ignition of that which follows.

600. Oil lamps and candles may be considered, in a practical point of view, as small gas-manufactories, the gas being developed on the wick where it is also consumed. Essentially, therefore, it is always gas that burns, whether an oil lamp, a candle, or a gas lamp be used.

601. In all cases, where ordinary inflammable matter burns, the combustion depends on the oxygenation of the carbon and of the hydrogen.

602. Carbonic acid being the product of the full oxygenation of carbon, and water the product of the oxygenation of hydrogen, these two substances tend to accumulate in the atmosphere of all apartments, where candles, oil, or gas are used in the ordinary manner.

603. If air in excess be mingled freely with the inflammable

matter, so that any carbon, as it is separated, shall be instantly, and, at the same moment, oxygenated, the flame is never brilliantly luminous, but of a pale blue colour ; this tint may be always observed at the base of the luminous cone of a common candle.

604. If air be supplied less freely, part of the carbon is suspended in the flame for a short time before it is consumed, and is then precisely in the same condition as a white-hot cinder in a furnace.

605. If the combustion shall proceed so that the carbon is separated, but not heated to the same extent as in the last case then the light emanating from it is less brilliant and rather red than white.

If the supply of air be defective, so that part of the separated carbon does not receive oxygen, a lurid appearance is presented, and unconsumed carbon finally produces a black smoke.

606. If any cold material, as a slip of glass, be held in the white-hot flame, part of the carbon is deposited upon the glass.

607. Though the same products are evolved in general from oil, tallow, wax, and gas, minute and special differences may commonly be observed in consequence of portions of tallow, oil, or gas escaping combustion, and being dissolved or suspended in the atmosphere. Special sources of contamination may also be observed at times, as where the fatty matter of candles has been hardened by arsenic, or where gas may not have been sufficiently purified from sulphureous compounds, the arsenical and sulphureous compounds then formed increasing greatly the deleterious properties of the products.

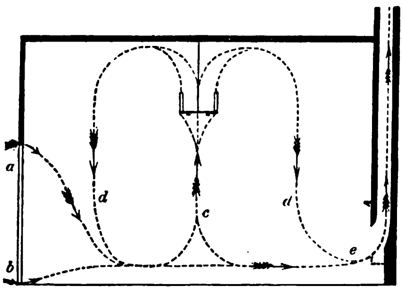
608. In considering the influence of the products of combustion formed during artificial illumination, even where no peculiar impurity is presented, it will be noticed that they are as destructive and offensive to animal life as those formed by ordinary fires. It is desirable, accordingly, to discharge them by a chimney or some other means, in the same manner as those from the common fire. But where the amount of illumination is small, and the apartment is otherwise ventilated, the amount of moisture and carbonic acid may be too trifling to render this necessary.

On the other hand, where the illumination is great, the products ought to be removed directly, however pure the oil, tallow, wax, or gas may be that is employed. Gas, when pure, does not evolve, during combustion, products that are more offensive than wax, tallow, or oil; but from its economy as an illuminating power, a large amount of it is, in general, used where it is introduced as a substitute for other lights. Further, all rooms lighted with gas, where special arrangements are not introduced for ventilation, are subject to the evolution of minute portions of unconsumed gas; the necessary ventilating arrangements for preventing this will be shewn in future paragraphs.

609. Another peculiarity connected with gas-lights burning in ordinary apartments requires special attention, viz., their extreme tenacity of combustion. Gas-lights burn for a considerable time in atmospheres so loaded with carbonic acid, moisture, and nitrogen, as to extinguish oil-lamps and candles, or to render their combustion comparatively feeble. They do not, therefore, so promptly indicate a gradually deteriorating atmosphere; the nature of the gas burner used also affects the duration of the flame in vitiated air. The reason of this peculiarity in gas is abundantly obvious on considering that an ordinary gas-lamp is provided with gas already formed by the action of heat, whereas oil, wax, and tallow require heat for the production of the gas beyond what may be necessary for its combustion.

610. In the accompanying figure (178), the ordinary progress

Fig. 178.



of vitiated air from lamps, candles, or gas-lights may be traced. All vitiated air from oil-lamps, or other lights, if not constrained

in its movements by any local current, passes directly towards the ceiling of the apartment in which they are placed, recoiling or descending from it as successive portions of warmer air displace it, and as it is subsequently involved in streams of fresh air passing from doors or windows to an open fire. Accordingly, all air above the level of the discharge may be intolerable, and loaded with the products of combustion, while a less impure atmosphere prevails below; *a* and *b* indicate the entrance of fresh air; *c* an ascent to the lamps; *d d* the descent of the vitiated air, and its mixture with fresh air proceeding to *c* and *e*.

611. It will be obvious from the preceding illustration that the great object in all cases, must be to drain off, directly from the ceiling, such products as lamps and candles may incline there; and, if a sufficiency of fresh air be not introduced so as to expel these products with certainty, and prevent their returning to the zone of respiration, then, if it still be an object to prevent entirely their contaminating influence, these products should not be permitted to extend generally into the apartment, but be conveyed at once from the place where they are formed to the channel by which they are to escape.

612. Exclusive Lighting consists essentially in the application of the principle now explained. The light may be arranged in any of the three following modes, according as circumstances may permit.

1. Entirely or absolutely exclusive, the lamp being without the apartment, and its light entering as the light of day passes through the glass of an ordinary window.

2. Essentially exclusive, the lamp descending in the apartment, but being supplied with air from without, while it is hermetically excluded from having any communication whatsoever with the air of the apartment.

3. Practically exclusive, the lamp being supplied with air from the apartment which it illuminates, and the products of combustion being conveyed directly from it by an appropriate channel without contaminating the air in the apartment.

613. The following illustrations in this chapter, and those in

R

the succeeding part,* explain the more important varieties of gas-lamps, and the manner in which they may be ventilated. It is scarcely necessary to add, that oil-lamps may be treated in the same manner.

614. In all cases where large lamps are used, and where much heat is developed, additional ventilation is often required, in consequence of the amount of radiant heat which they emit, though the products of combustion be entirely carried away. This is more essentially necessary when the lamps used are placed near enough to affect parties who have not the opportunity of changing their position in respect to them.

615. In a common candle, gas-jet, or plain oil-lamp, the entire surface of the luminous cone is on fire. The most brilliant combustion is a little above *a a*, Fig. 179. In the lower part of the flame, the excess of air and deficiency of heat and suspended carbon prevent the light from being powerful. In the highest part of the flame, the light is imperfect, when, from the diminution of temperature, or deficiency of oxygen, part of the carbon escapes combustion and produces smoke.

Fig. 179.

616. In the interior of all ordinary flames, there is unconsumed gas, and by a tube introduced into it, as in Fig. 180, part of this gas may be conveyed to a distance and inflamed, passing from *b* to *c*, where it is kindled on applying a light.

Fig. 180.

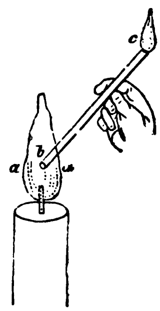
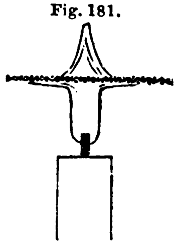


Fig. 181.

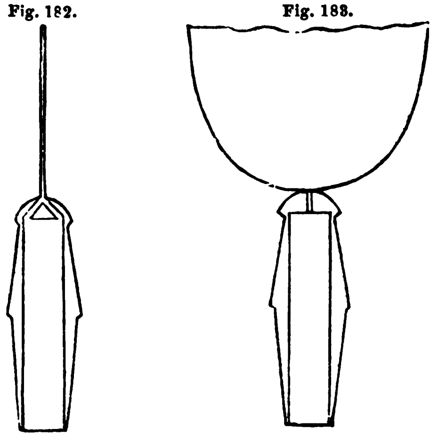


617. If wire-gauze be held over the flame of a candle, as in Fig. 181, the structure of the luminous cone becomes beautifully apparent on looking perpendicularly upon it. The unconsumed gas from the interior of the cone may be kindled by applying a light above the gauze.

* See Experiments with Gas at the House of Commons.

618. The accompanying figures explain the form and structure of one of the most perfect varieties of gas-jets; 182 indicates

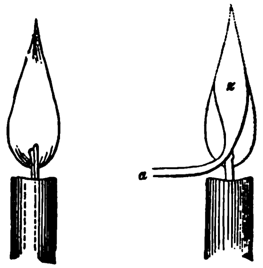
Fig. 182. Fig. 183.



more particularly the form which the flame generally presents, and 183 shews a transverse section of the same flame, and of the channels by which the opposing currents of gas are led to strike against each other, and to flash consequently into an exceedingly thin sheet of flame. The burning surfaces are exceedingly near each other, the gas between them is intensely heated, much gas is decomposed before it burns, much charcoal is temporarily suspended in the flame, becomes highly luminous, and is consumed without loss or visible smoke from the high temperature to which it is subjected.

619. In the ordinary argand lamp similar effects are produced, but not to the same extent, by causing a stream of air to pass into the interior of an ordinary flame. If, into an ordinary flame, having the figure shewn in 184, air be introduced by a tube *a*, Fig. 185, the form of the flame is instantly altered; the original outline of the flame, indicated by the dotted line, disappears, and it assumes the tulip-shape that is seen on either side of *z*. The flame has now be-

Fig. 184. Fig. 185.



come an ARGAND flame, and the oil or gas argand lamp only gives a more convenient mode of sustaining the same arrangement.

620. If the supply of air passing to the interior of an argand lamp, burning with a flame such as Fig. 186 shews, be cut off,

Fig. 186.

Fig. 187.

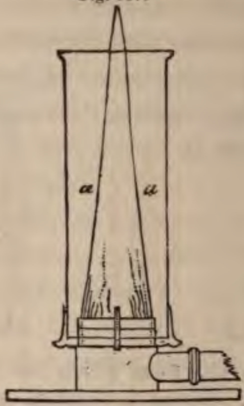


Fig. 188.

by closing the central aperture below, immediately the flame is extended as in 187, the gas burning only on the external surface, as at *a a*; whereas the surfaces in combustion in an argand properly supplied with air are much nearer, as at *a a* in Fig. 188.

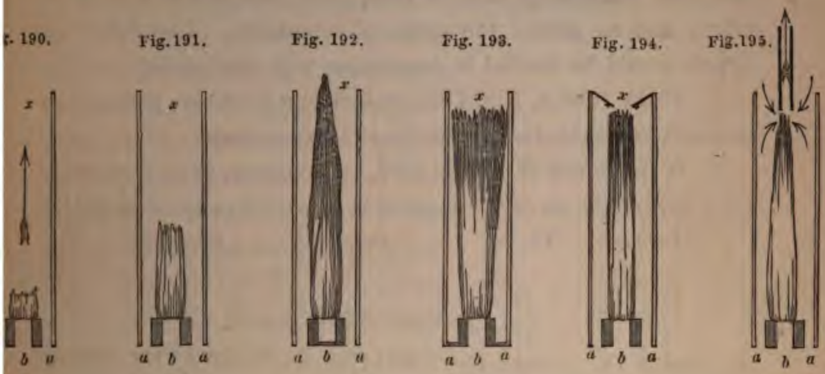
621. In the solar lamp arrangement, instead of air being permitted to ascend, in the usual manner, around any flame, it is forced, by using a curved glass or metallic director, to strike against that part of the flame where it is most important to have a sufficient and controlled supply of air; the thick curved line between *a* and *b*, Fig. 189, indicates one of the modes of arranging the director in solar lamps.

Fig. 189.

622. In argand lamps the most brilliant flame is not necessarily that which is best adapted to all the circumstances under which they may be used. Figs. 190 to 195 inclusive, show varieties of form, length, and brilliancy of flame, induced according to the mode in which air is supplied, and the relative amounts of gas and air that are used.

1. An excess of air entering externally by a, a, and internally by b, causes a short and feebly luminous flame, Fig. 190.

2. Every burner produces a maximum of light, when the most perfect combustion of the largest amount of gas it can consume is accompanied by the largest amount of luminous surface than can be produced without smoke. A flame, as large as is shewn in Fig. 191, may often be obtained with no more gas than



produces the short flame seen in Fig. 190, if the burner be disconnected with any flue where the draught might have been excessive.

3. A deficiency in the supply of air, produced by closing the aperture b (Fig. 192), a, a (Fig. 193), or x, 194, may alter the appearance and length of the flame, as these figures explain; unless excessive, it is not accompanied by smoke.

623. By introducing discharging tubes, as in Fig. 191, the flame may also be modified according to the extent to which the tube may act upon it, the descent of a certain portion of cold air at the top retarding the ascending current that otherwise passes from below, and making it less available, accordingly, for the supply of the lamp.

624. The preceding figures having explained the great variety of appearance which flame assumes, according to the mode in which air is supplied to, and withdrawn from it, it is scarcely necessary to remark, that by controlling completely both

the ingress and egress of air, great power is acquired in giving any peculiar complexion to a gas-light that may be required.

625. In ventilating gas-lights, and other lamps, the same principles should be applied that regulate ventilation where noxious products are to be withdrawn from any apartment. In particular, *they should be removed at once, and prevented from mingling with the general atmosphere of the apartment.* Were this more constantly kept in view, gas-lights would not be so often, and so justly, the cause of complaint. The following figures should be studied in connection with this subject—

1. If the tube *a*, Fig. 196, be deficient in power, part of the products of combustion escape into the apartment.

2. If the power of *a*, Fig. 197, be excessive, then, as in Fig. 195, part of the air of the apartment is carried away,—an object

Fig. 196.

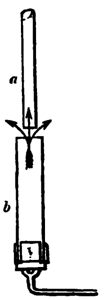


Fig. 197.

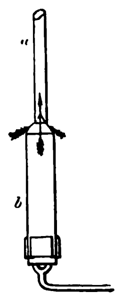


Fig. 198.

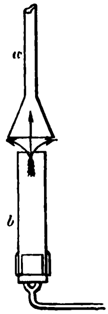
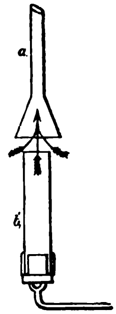


Fig. 199.



of no consequence, but rather desirable, in general, where there is power to spare.

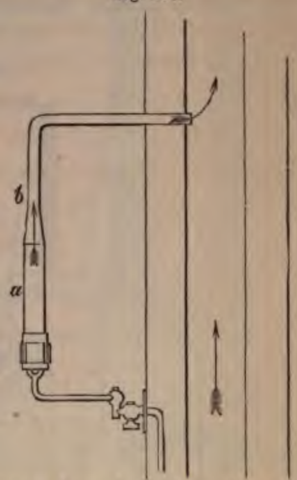
3. If the ventilating tubes terminate in wide fiunnel-shaped apertures, as in Figs. 198, 199, these do not, where there are any local currents, act better than the smaller tubes. They involve, in reality, all the objections of the old chemical hood, where bad vapours were withdrawn, after contaminating, in general, a considerable portion of air, instead of being at once removed by a ventilating power, acting where they were produced.

626. From the preceding illustrations, it may be inferred, where it is desirable to secure the effective ventilation of

the gas-burner, with the least possible power, and in some cases also, with the smallest ventilating tube applicable, no mode is so important as that which connects the ventilating tube directly with the burner, as is seen in Fig. 200. If a valve be placed in the ventilating tube, it may be employed to regulate the amount of air supplied to the gas-lamp, by checking the products which pass from it.

627. The figures, representing the arrangements made for the ventilation of the gas-burners in the experimental apartment constructed at Edinburgh, in the year 1836, for determining various points bearing on the ventilation of the House of Commons, give more extended illustrations of exclusive gas ventilation (See Part V.), where none of the products from the gas could mingle with the air of the apartment. Means were also provided, which prevented any gas escaping by leakage from entering the apartment.

Fig. 200.



628. Since that period, various burners have been introduced, in which the same mode of ventilation has been adopted.

629. In the original BUDE-LIGHT, introduced by Mr Gurney, oil and oxygen were used, but now air and coal-gas are employed. Its nature would have been more generally understood had it been termed an IMPROVED GAS-BURNER. In this very valuable light, concentric rings of gas are used in the same manner as concentric wicks are used with oil in Fresnel's light-house lamp. It is sometimes made with great simplicity of form; in other cases, extended arrangements are introduced in unison with the peculiar circumstances in which it may have to be employed. The temperature to which the gas is heated, as it emerges from the gas tubes, enables it to afford precipitated carbon at the instant it escapes from them, and, accordingly, the luminous surface is

larger than is observed in gas emanating from a comparatively cold metallic tube. Where there is no objection to a bright light, or to obscured glass, the present form of the plainest varieties of bude-lights include many advantages. The temperature to which the gas is exposed, before combustion, should be reduced so as to prevent any deposition of carbon within the gas-tubes.

630. Figs. 201 and 202 shew the gas lamp described by Mr Gurney in the Repertory of Patents. a is the gas flame;

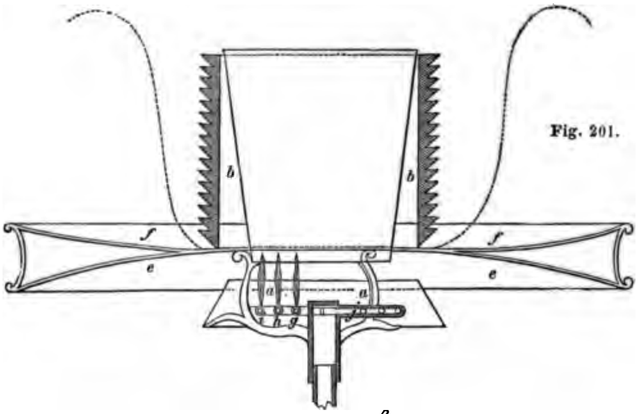


Fig. 201.

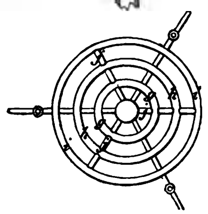


Fig. 202.

b the chimney; e and f, two reflecting surfaces; the reflecting surface e, diffuses the light of that portion of the flame which is below it, downwards; the reflecting surface f, diffuses all the light of the part of the flame which is above it upwards. The dotted lines shew the application of a ground glass refractor above the reflectors; a refracting zone is placed above the re-ctors, which consists of a cylinder of glass, cut on the outside › prismatic projecting rings at such angles as to direct the

light in the desired directions. The figs. also shew a section and plan of a burner made of concentric rings, *g*, *h*, *i*, of tubing, perforated on the upper surface; *b* shews the upper glass chimney of the burner.

631. In the large Boccius Burners, which are represented by Figs. 203 and 204, two metallic chimneys, placed in a peculiar manner in reference to the flame, and concentric burners, such as are used for the bude-light, but elevated above each other, constitute the principal peculiarities. A, the crutch; B B the concentric rings; C the wires for supporting the metallic chimneys; D the space between the metallic chimneys; E the flame; F the space between the outer metallic chimney and the glass chimney which surrounds the whole.

Fig. 203.

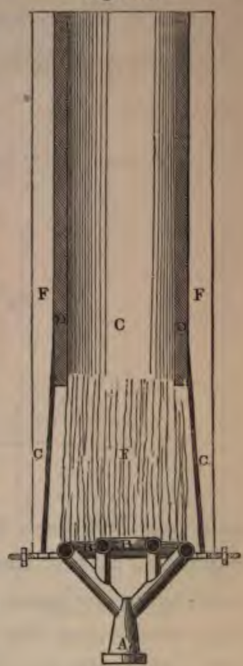


Fig. 204.

632. Figs. 205 and 206 shew a plan and section of Dr Faraday's ventilating gas-burner;—*a* is the burner; *b* the gas-pipe leading to the burner; *c* the glass-holder, with an aperture in it opening into the mouth-piece *d*, which is attached to the metal chimney *i*; *e* the ordinary glass chimney; *f* the outer cylinder of glass closed at the top by a plate of mica, *g*, or still better, by two plates of mica, one resting on the top of the glass, and the other one, *h*, dropping a short way into it; they are connected together by a metal screw and nut, which also keeps them a little apart from each other; *i* the metallic tube chimney; *k* a ground globe which may be applied to the lamp, having no opening except the hole at the bottom. Fig. 206 shews more particularly the burner *a* in the centre, around

which the fresh air enters, and the aperture *d* which opens into the mouth-piece connected with the metallic chimney *i*. The

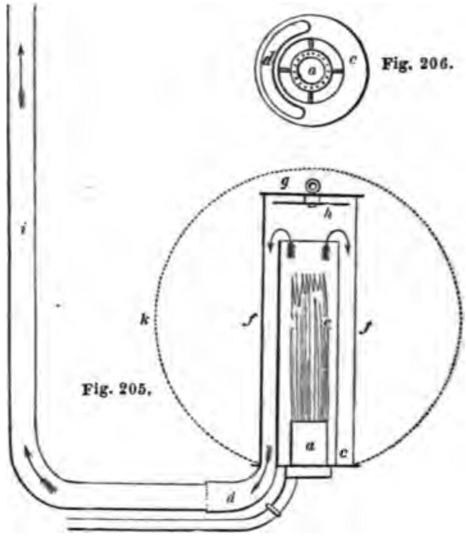


Fig. 206.

Fig. 205.

principal difference between this and the exclusive burner, I explained at the Royal Institution in the year 1842, is the descending movement given to the products of combustion after they escape from the luminous cone or flame, and before they are conveyed to the tube by which they are discharged. This descending movement will prove very advantageous, where it may be desirable to display the gas in special lustres, and to combine with this the advantages of exclusive lighting in the manner recommended.

633. With this exception, burners from which the air ascends directly have the following advantage :—

1. They require no forced current to commence their action, whereas the descending burner cannot be kindled, except under nfluence of a forced draught.

The heat produced by the combustion of the gas is ca-

pable of being more quickly withdrawn by its direct ascent, an object which is often of great importance in some apartments, and which has been secured to a greater degree in the Gothic pendant exclusive burners, than by any other mode, except where the light was placed altogether out of the apartment. But in the descending burner, a glance at its form will shew that it must necessarily retain a larger amount of heat at a lower level, than those lamps where the products of combustion ascend directly from the burner.

634. Figs. 207 and 208 represent the most powerful gas burner I have hitherto used for the purpose of illumination. It was one of those made by Mr Faraday of Wardous Street, according to a plan by Mr Manby. The glass cylinder with which it was employed being too liable to break, I substituted a mica cylinder, ten inches in diameter, and 18 inches long. At the masque ball at Buckingham Palace, this burner was placed over the throne, and ventilated by a communication established between it and one of the chimneys. It was subsequently placed in Tippoo Saib's tent.

Fig. 207.

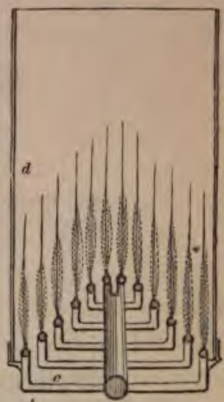


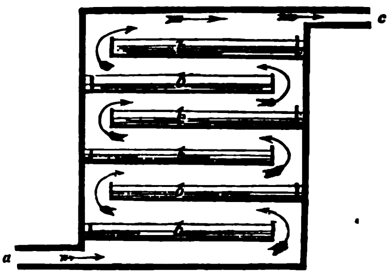
Fig. 208.

635. The effect of this burner was greatly increased by causing the gas used to pass over warm naphtha, when it became more luminous according to the amount of oil absorbed. The arrangement for this purpose, recommended by Mr Lowe, has many advantages, where gas is used that is not powerfully illuminating. The annexed Fig. 209, represents one of the naphtha boxes, containing many trays of this liquid over which the gas is made to pass that it may imbibe the naphtha.

636. Where a central light of great power, though subse-

quently equalized by obscured glass, or otherwise, is not considered suitable, a series of flat jets thrown into circles, often

Fig. 209.



presents a very pleasing effect. The annexed Figs. 210 and

Fig. 212.

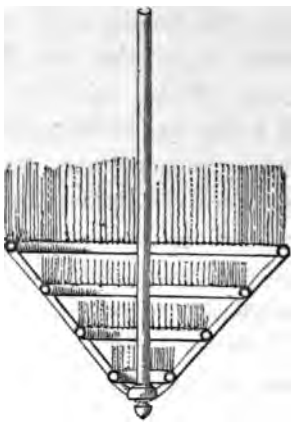


Fig. 210.

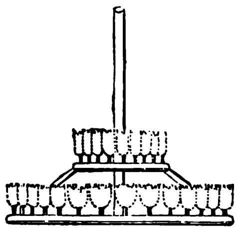


Fig. 213.

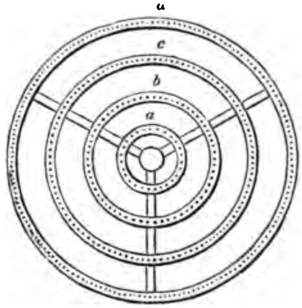
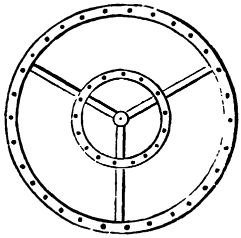


Fig. 211.



1 represent one of these double circles, which produced a

very pleasing effect in the apartment in which it was placed, the ventilation having been sufficient to carry away all the vitiated atmosphere it produced.

637. Figs. 212 and 213 represent a different form of burner, which may be introduced, with advantage, in peculiar situations, where a sufficient ventilation can be commanded; but it is not regulated with facility, and presents no special recommendations where the form of the light, as seen from a distance, is not an object. Mr David Cowan (Hungerford Street, in the Strand) has lately introduced an argand ring burner, which he prefers to the ordinary form of the argand burner.

PART IV.

VENTILATION OF THE PRESENT HOUSES OF PARLIAMENT.

---

638. In the year 1835, on the motion of Benjamin Hawes, Esq., M.P., a select committee was appointed by the House of Commons, "to consider the best mode of ventilating and warming the New Houses of Parliament, and of rendering the same favourable to the transmission of sound, and empowered to extend their inquiry to the present houses." The committee, after examining different witnesses, having recommended that "some, if not all, the alterations suggested" by the author, "should be submitted to the test of actual experiment," very extensive alterations were made under his direction in the autumn of 1836, after a communication which ensued between Mr Hawes and the Chancellor of the Exchequer, and the Commissioners of Her Majesty's Woods and Forests.

639. Dr Reid is glad to have this opportunity of acknowledging the valuable assistance and advice which he received from Mr Hawes, the Chairman of the Committee, on acoustics and ventilation. Nor can he omit expressing his great obligations to Lord Sudeley, the chairman of the commissioners appointed to select the design for the New Houses of Parliament, especially for his kindness in designing the architectural arrangements, which so materially advanced the progress of the operations. He had also the advantage of frequent communi-

cations with Benjamin Smith, Esq., another member of the House of Commons' committee, who had paid much attention to the objects the committee had in view.

640. The defects complained of were the imperfect communication of sound, and the state of the ventilation. The subject will be most conveniently considered under three separate heads—viz. Ventilation, Lighting, and the Communication of Sound. In the House of Peers, the ventilation was altered three years after the first experiments made at the House of Commons; but as they were not carried to the same extent, a shorter notice is given of it in describing the ventilation of the House of Commons.

641. Previous to the appointment of the committee on acoustics and ventilation, the state of the atmosphere in both Houses of Parliament appears to have again and again attracted attention from the time of Sir Christopher Wren to Sir Humphrey Davy. Numerous references are made to the condition of the air in the House, which is often described as foul, rancid, or pestiferous. I understand from Mr Bellamy, that so late as in 1790, charcoal braziers were used for heating the House, no means being taken to carry off the carbonic acid produced before the members assembled. The following quotation is taken from the report of a committee appointed in 1791 :—

"Upon consideration of the several plans laid before them, your Committee think that the first proposition in the plans of Mr Holland, for carrying off the foul and rancid air from the House, the estimate of which amounts to L.45 ; the plan of Mr Walker for regulating the temperature of the air in the House, the estimate of which amounts to L.120 ; Mr Jones' plan for the thermometers, amounting to L.14, 14s. ; and the plans of Mr Bramah, contained in Nos. 1, 2, 4, 5, and 6, amounting to L.405, 12s. ; should be carried into execution as soon as possible.

"And for the purpose of making a proper experiment of the powers of Mr White's machine, your Committee think that the

Clerk of the Board of Works should be directed to take the most proper method of opening the curved work upon the cornice of the octagon ornament in the centre of the ceiling of the House, so as the foul air may be conducted from thence to the place where Mr White's machine may be placed."—*Commons' Journals*, vol. xlvi. page 415, 15th April 1791.

Various other committees were appointed between the years 1800 and 1835.

CHAPTER I.

VENTILATION.

642. THE great basis of all ventilating arrangements is the amount of supply which may be considered adequate for the apartment to be ventilated. Entertaining the conviction that no satisfactory progress would be made in the systematic ventilation of buildings, ships, or mines, till this primary question was settled, and that erroneous estimates on this point had done more to impede the progress of ventilation than any other cause, a series of apartments were constructed at Edinburgh, in which numerous trials were made previous to the commencement of the alterations made in the House of Commons, the arrangements introduced in the largest of these having placed the supply of air, both as to quantity and quality, entirely under control, and the experiments having been made with numbers, varying from one individual to two hundred and forty persons. The result of these experiments having confirmed me in the opinion I had formerly acted upon, the following leading alterations were made in the present House of Commons, formerly (before the great fire) the House of Peers.

1. The area of the discharge was increased to 50 feet.*

2. A power was placed upon it, so as to increase many times its effective action. In the former arrangements, smoke from a small furnace has been known to return by the ventilating aperture. I am not aware of any one case where there has been a return of vitiated air by the present arrangements, since they were finished in 1836.

* In Sir Humphrey Davy's plans, when it was the House of Peers, the area of discharge was one foot.

3. The area for ingress of air was equally increased.

4. The descent of cold currents upon the head was entirely stopped by an interior glass-ceiling.

5. The movement of air, from its ingress to its egress, was regulated as in a pneumatic machine, the house, in this respect, being treated as a piece of apparatus.

6. The hot apparatus was augmented and placed in a chamber, so as to be at all times in readiness, and afford, at a moment's notice, any amount of warm air that might be required.

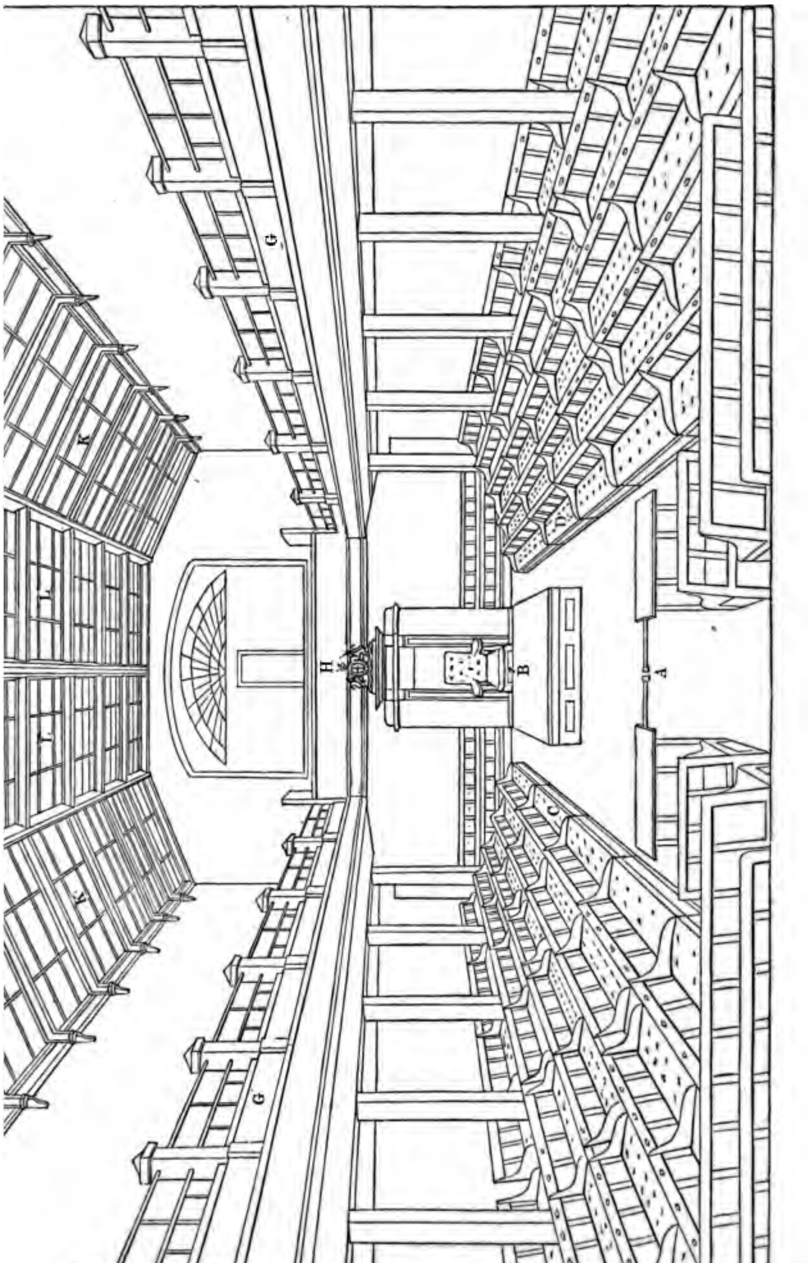
7. Mixing-chambers were provided, so as to allow the warm air to be mingled with any portion of cold air, according to circumstances.

8. An equalizing chamber was formed below the floor, that the local currents, otherwise apt to form unequal eddies, might be broken, and terminate in a uniform supply to every part of the floor.

9. The most extreme and universal diffusion was given in the floor, by piercing nearly a million of apertures, and breaking the force of the air passing through them by a porous and elastic hair-cloth carpet.

10. Arrangements were made in the lobbies by the alternate disposition of mats, and of Russian scrapers, in the floor of the lobby, to secure the greatest possible exclusion of every source of impurity that could affect the air. These arrangements engaged attention for some months before they were satisfactorily adjusted; by a new disposition of the seats, a suffcient diffusion may perhaps be obtained ultimately without permitting the air to pass through any place which the foot may touch. Universal diffusion, however, to the most extreme degree possible, is the great desideratum, that local currents may be entirely arrested, and every place have a like share of fresh air with the least possible movement.

11. The galleries were supplied with fresh air, the force of the movement induced there repelling the vitiated air which ascends from the floor below.


G
K
L
H
B
A
D
C
L
K
G

12. A chamber was provided for moistening, drying, cooling, and producing other alterations in the air, besides those effected by the hot-water apparatus. This chamber was provided from the commencement, and on one occasion, shortly after the House opened, subsequent to the completion of the ventilation, seventy gallons of water were evaporated at a single sitting.

13. A veil was provided, forty-two feet long by eighteen feet six inches deep, for excluding visible soot. By this, in the worst state of the atmosphere, it is found that 200,000 visible portions of soot are sometimes excluded on a single evening.

14. The air, from the principal drain in Old Palace-Yard, which contaminated the air entering the houses, was controlled and conveyed away by an under ground ventiduct communicating with the shaft.

15. Numerous other sources of offensive air were controlled in the same manner.

16. The quantity of air supplied to the House of Commons was placed under the control of a single valve, so that the movement could at any time be arrested at a moment's notice, or adjusted to any proportion between zero and the highest power that can be commanded.

643. After these explanations, a few memoranda will be sufficient to explain the following diagrams, illustrative of the alterations made for sound and ventilation.

644. Fig. 214 gives a view of the present House of Commons. A the bar, B the table before the Speaker's chair, C the minisferial side, D the opposition, G the members' galleries, H the reporters' gallery (the strangers' gallery is opposite to it), L, L, the ceiling forming the base of the foul-air ventilating chamber, K, K, glazing, extending from end to end of the House of Commons, introduced for improving the communication of sound, for the diffusion of light, and for preventing cold air from being precipitated from the external windows.

645. Fig. 215 (plan) shews the lower air-chamber T, T, into which the air flows by the cold-air passage A, from the first or receiving chamber C, C, C, the doors *b*, *b*, of the heating appa-

ratus *d*, *d*, *e*, being closed. The air is admitted into C, C, C, by numerous appertures from the external air. Apparatus for

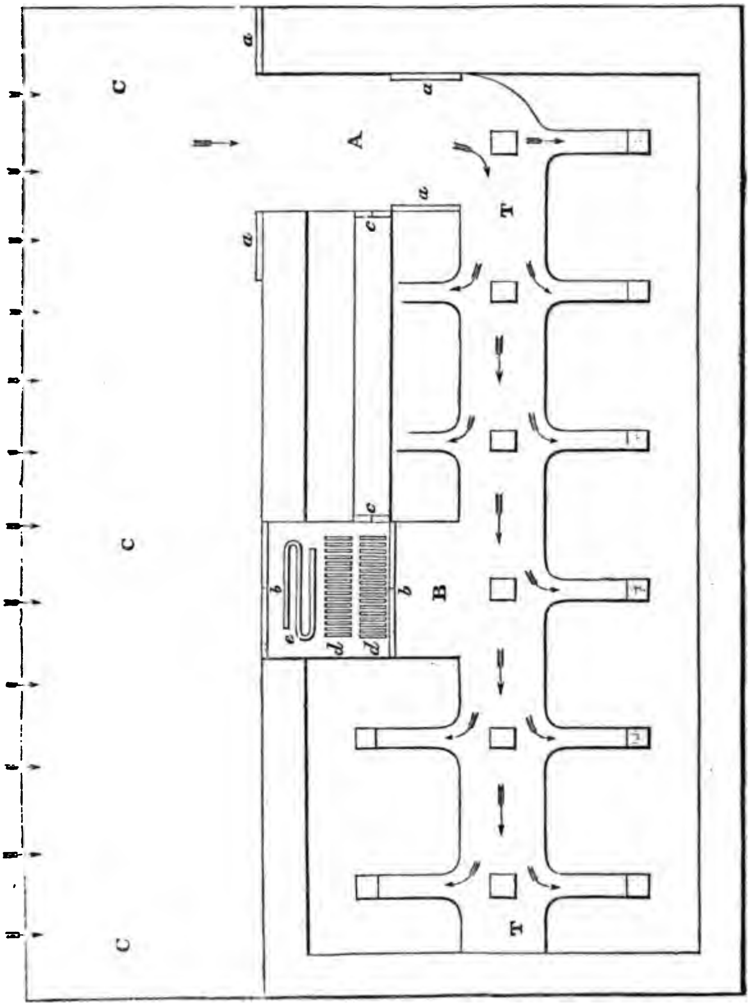


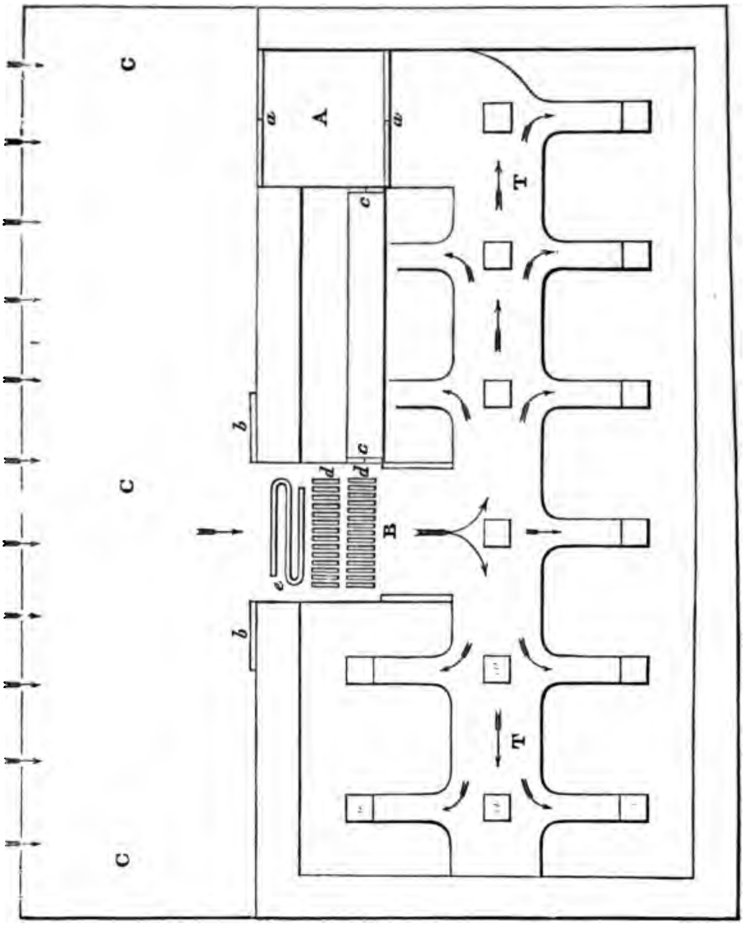
Fig. 215.

cooling the air may be placed in C, C, C, or A. The air having reached T; T, escapes into the equalizing chamber above it, by different apertures, represented in Figs. 218, 219.

646. In Fig. 216, the progress of air from C, C, C, is shewn

when it passes along the heating apparatus *d, d, e,* in B, the door *b, b,* being thrown open, while those, *a, a,* of the cold-air passage A, are shut.

Fig. 216.



Part of the hot air may be led at times through the communicating chamber *c, c,* when the doors there are opened, the outer door of A being shut, while those within are opened.

647. In Fig. 217, the air is observed entering partly by the

cold-air passage, and partly through the communicating passage when the doors *c*, *c*, are opened, and the other doors, arranged in

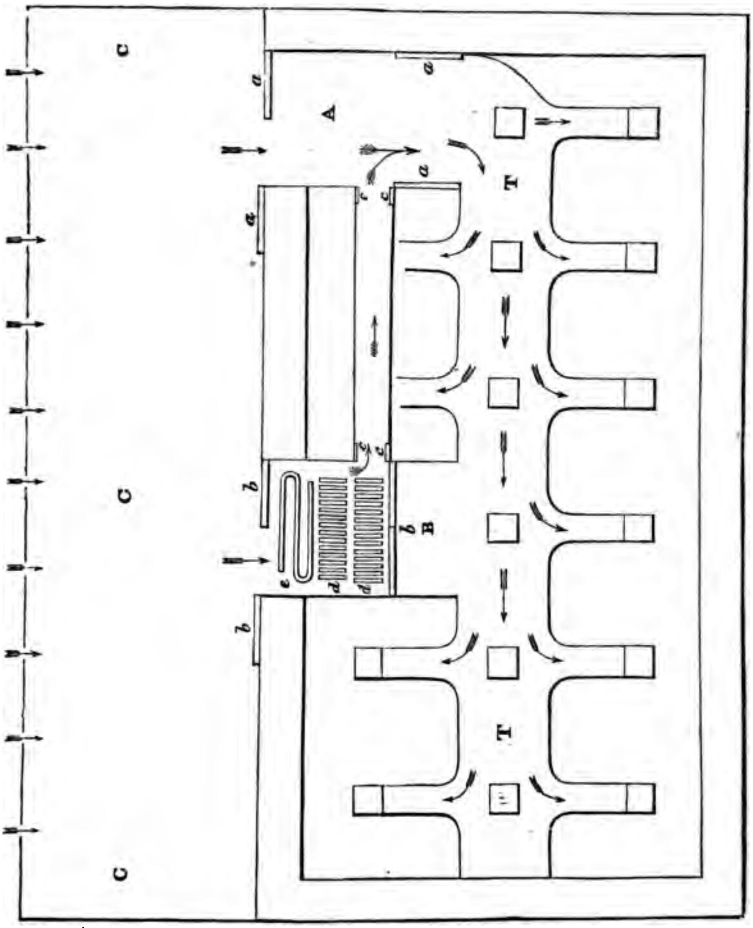


Fig. 217.

the manner represented, meeting at right angles with the cold air from A, so as to promote, as much as possible, a complete mixture.

Fig. 218.—As the air advances from T T to the equalizing chamber, between it and the floor, it strikes upon the dispersers L L L, and then flows in a slow, but uniform stream, through the

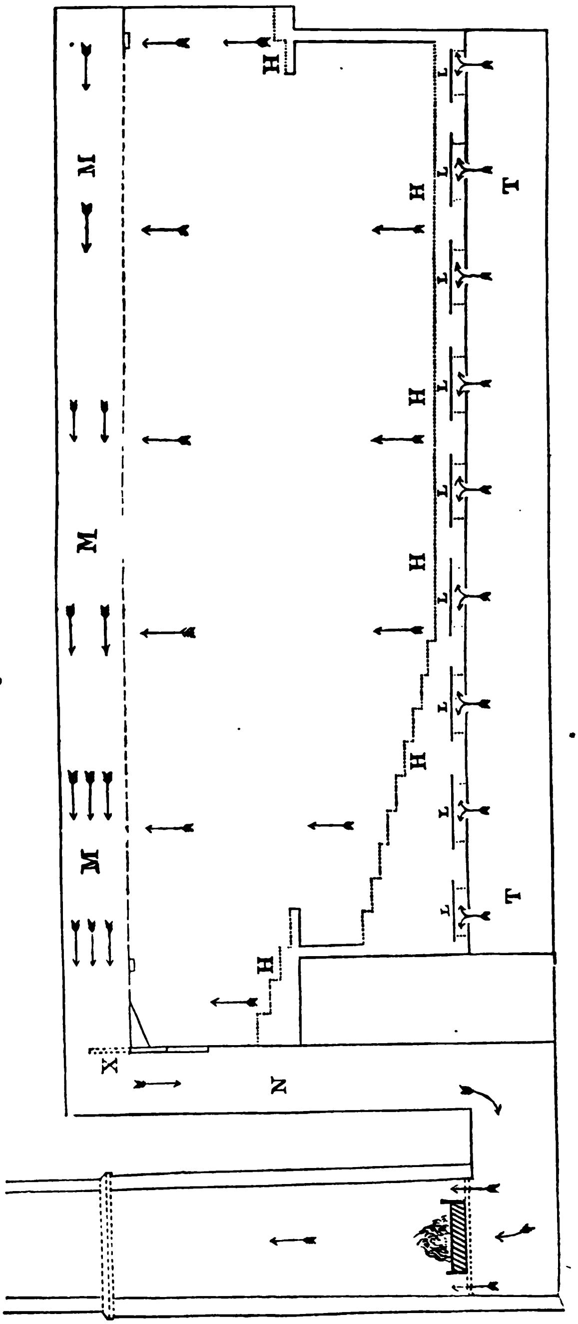
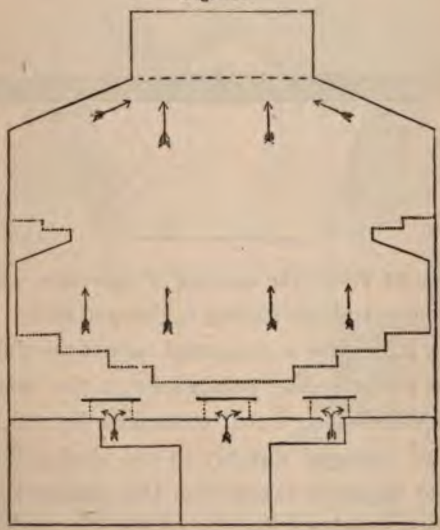


Fig. 218.

apertures in the floor, gradually escaping through the hair floor-cloth H H H, from which it ascends to the ventilator M M M, and descends by N, from which it passes to the air-shaft. The rapidity of the movement is regulated by the valve X, which can be opened entirely in a crowded house, or closed to any extent, according to the number of members present. The apertures in the upper ventilating tube increase in number as they recede from the shaft, a proportionally greater area being required to withdraw the air from the House in an equal stream. It will be noticed, also, that there are air-chambers below the floor of the galleries, communicating freely with the equalizing-chamber, so that there, also, fresh air is supplied through the perforated floor and porous hair-cloth H H H, in the same manner as in the body of the House. By bringing down the air from the ceiling to the ground, through the descending tube N, it is not necessary to elevate the shaft so high in the air as would have been required had it been placed on the roof, while the comparative security of the founda-

Fig. 219.



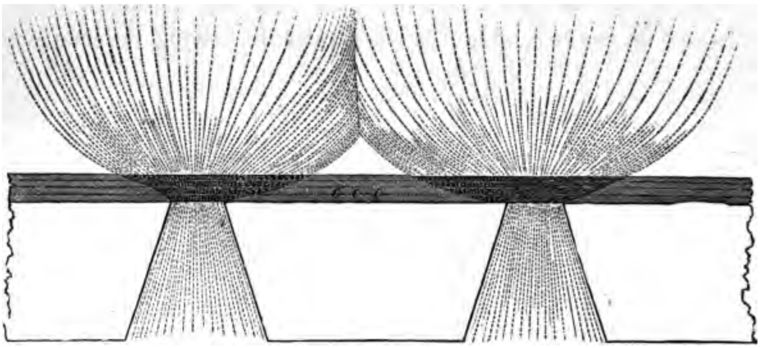
tion is also advantageous. But in buildings constructed origi-

nally with a view to ventilation, it is desirable to have no descent of warm air.

648. Fig. 219 gives a transverse section, illustrating the progress of the air from the tube below, by the different apertures, into the equalizing chamber, and from it through the floor, both of the galleries and body of the House, to the upper ventilating tube.

649. While the air enters with extreme freedom from the whole extent of every riser on the floor of the House of Commons, its ingress being merely equalized by the very porous hair-cloth that hangs before them, a still greater amount of diffusion is obtained by the perforations in the floor, the hair-carpet there producing a similar effect, and multiplying indefinitely the diffusion with which the air enters. Fig. 220 shews the amount of

Fig. 220.



diffusion given at first; the number of apertures was afterwards doubled. The central hair-cloth is changed daily.

650. Fig. 221 gives a connected view of the different points referred to in the preceding paragraphs; *a* the vitiated air from the drain in Old Palace Yard, controlled by the underground ventiduct, and conveyed directly to the shaft; *b* the fresh air entrance when the air is taken from Old Palace Yard, with the suspended fibrous veil, 42 feet by 18 feet, for excluding mechanical impurities; *c* temporary apparatus for moistening or wash-

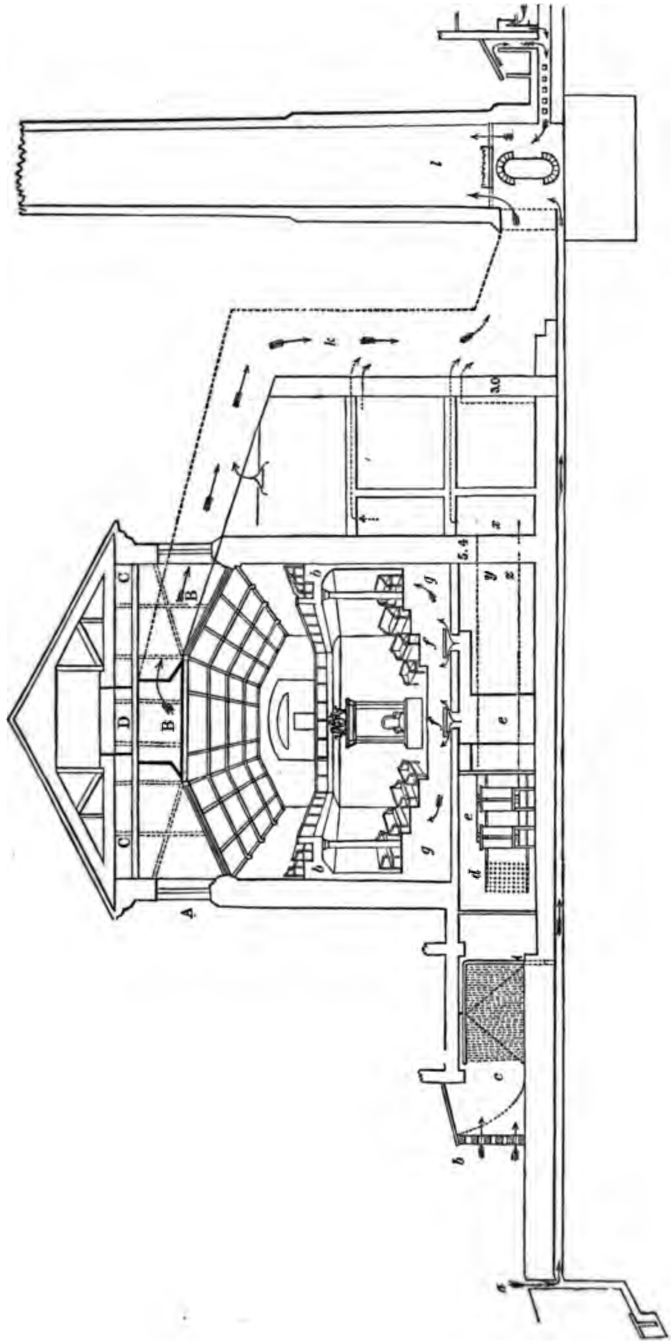


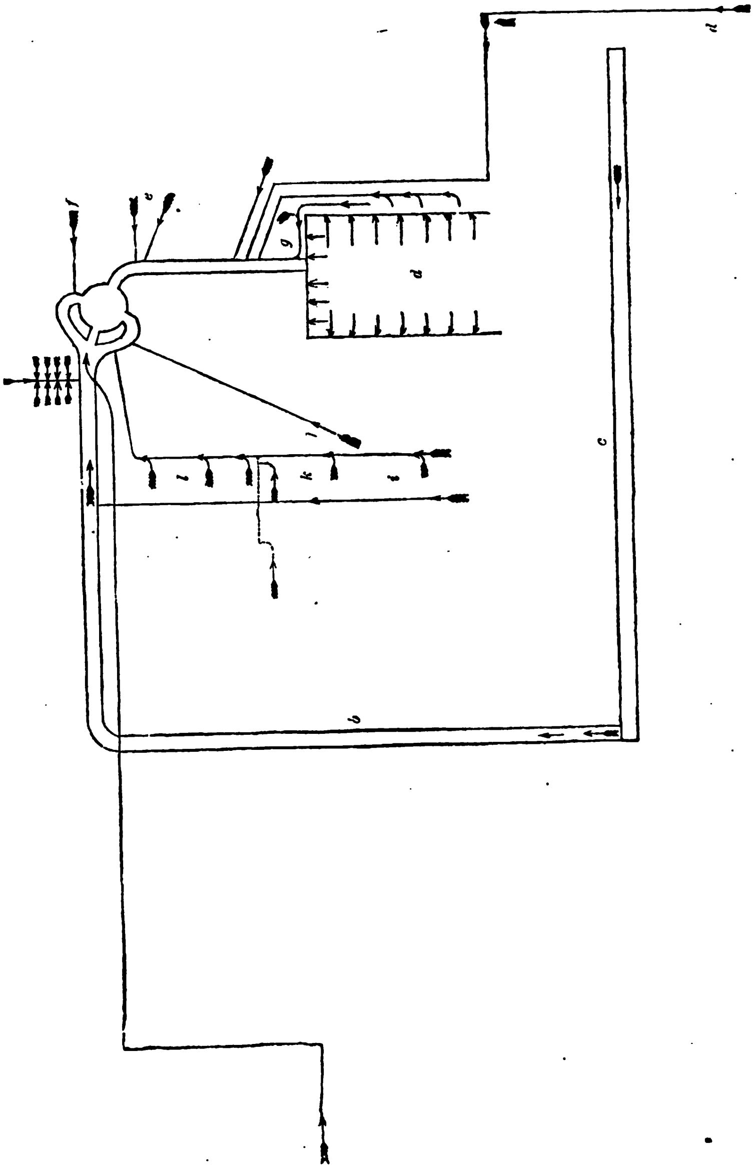
Fig. 221.

ing the air; *d e* the hot air chamber communicating with *e*, the lower air chamber, which receives warm, cold, or mixed air, according to the temperature required; *f f* deflectors for diffusing the air in the equalizing chamber *g g*; *b b* the supply for the galleries conveyed from *g*, by the channels between *b* and *g*; the dotted lines above *y*, and below *z*, shew the flow and return-pipes from the hot water boiler, which is placed at *x*, and supplies the hot water apparatus in *d e*. The large arrows from the ventilating chamber B, indicate the progress of the air to the ventilating shaft, while small arrows indicate the discharge of vitiated air from the libraries and various other places in the vicinity of the shaft. A indicates the external windows; C C the original altitude of the ceiling; and D the vitiated air channel from the House of Peers, communicating ultimately with the shaft that ventilates the House of Commons.

651. Fig. 222 is a scheme illustrative of the various apartments or vitiated air channels which can be controlled by the present shaft, every arrow indicating a special aperture upon which the shaft can be made to act.

a The drain in Old Palace Yard.
b The House of Commons.
c The House of Peers.
d Stoves, fire-places, and various apertures connected with the Experimental Room.
e Offices on the New Works.
f A dust-bin.
g Watchman's fire-place.
h Steam-boiler.
i Boiler-room.
k Apparatus-room.
l Waiting-room.
m Miscellaneous closets, &c.

652. In hot and sultry weather, the full power of the shaft is not too much for the House of Commons; but, as both houses are not often crowded at the same period, it is generally sufficient



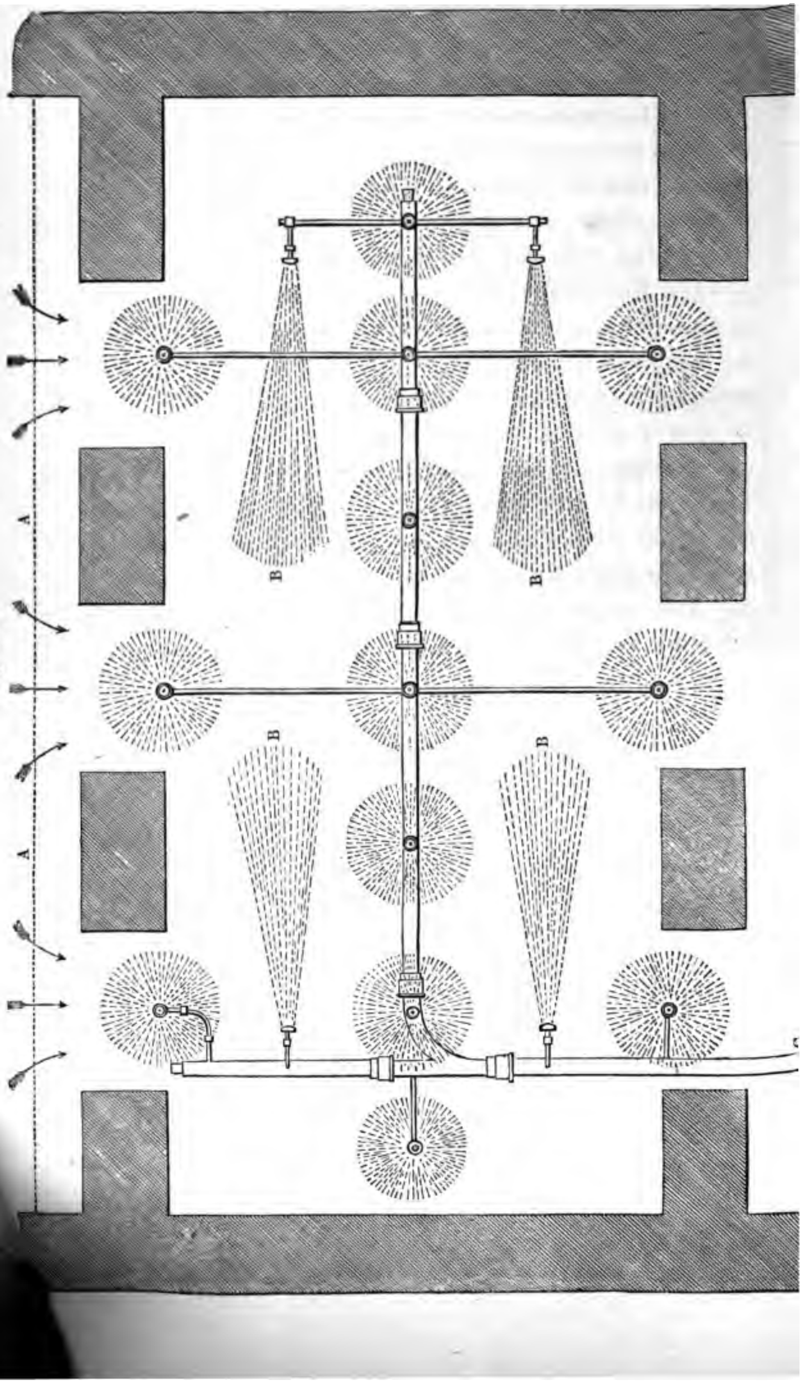


Fig. 223.

for all ordinary purposes, and when extra power is required, there are means for applying it temporarily at the House of Peers. Extra power is more especially necessary when members of the House of Commons crowd at the bar of the House of Peers to the extent of one upon every square foot. It may be necessary to remark, that the shaft was built originally for the House of Commons alone, but that it is abundantly sufficient for both houses when neither are crowded.

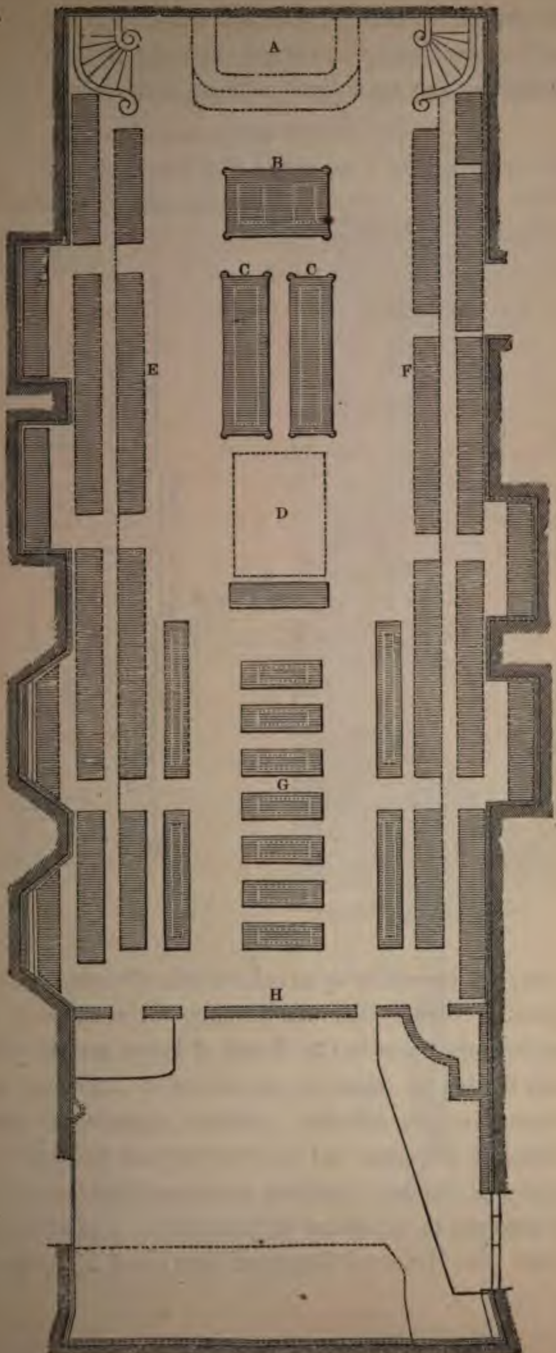
653. Fig. 223 represents another form of washing apparatus constructed in a vault under the present House of Peers, which has long been familiarly known as Guy Fawkes' vault. It was arranged in a temporary manner, at a very short notice, with the view of shewing the effect of drawing air loaded with soot and other matters, through myriads of particles of pure water, or water charged with lime or other absorbents of offensive impurities. The air, in entering through the gauze A, deposits the more gross mechanical impurities. Minuter particles, which may have escaped the gauze, are detained by the particles of water formed by the dashing of the fountains upon the walls, and arrested ultimately by a second or a third gauze veil through which the air must pass. The amount of water given in this temporary arrangement is regulated by a valve placed upon the pipe C. It is scarcely necessary to mention, that the water cools and moistens the air, besides retaining the impurities mentioned. The air from this chamber can be conveyed to the House of Commons, as well as to the House of Peers, when the air in Old Palace Yard is of very inferior quality.

654. Fig. 224 is a view of the present House of Peers, A the throne, B the woolsack, C the judges' seats, D the table, E the ministerial seats, F the opposition, G the cross benches, H the bar.

655. Fig. 225 is a plan shewing the disposition of the seats in the House of Peers, in which the references are the same as in the preceding figure.

656. The House of Peers was ventilated several years after the House of Commons, and the ventilation was arranged essen-

Fig. 225.



tially in the same manner; but the principles applied at the House of Commons not being carried out to the same extent, a very great difference may be noticed between them, whenever the cir-

Fig. 226.

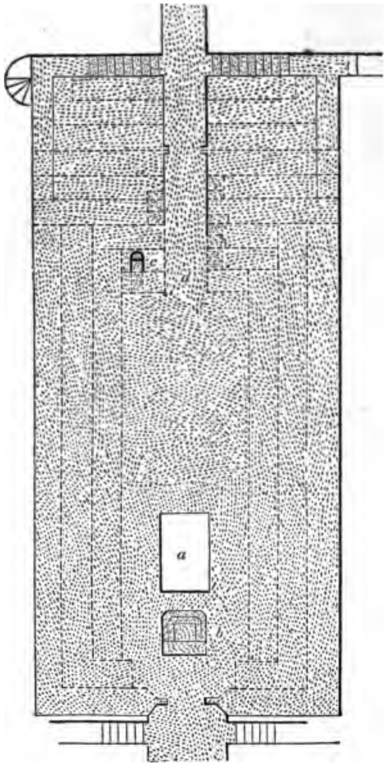
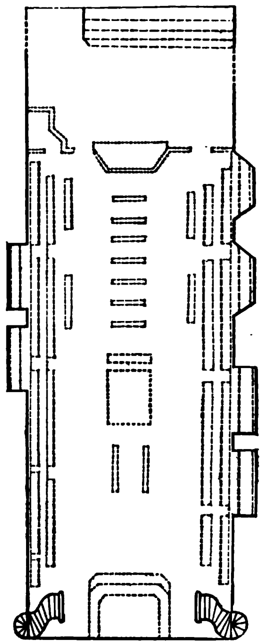


Fig. 227.



cumstances are trying, so as to call for full, efficient, and diffusive ventilation. In particular, the mixing, the equalizing, and the diffusing arrangements in the House of Peers are not placed on the same footing as those in the House of Commons, while its proportions, unequal galleries, extreme altitude, the numerous doors which it presents, and the crowds that frequently collect below the bar, render it subject to many disadvantages which are not observed in the House of Commons. The accompanying Figs., 226 (the House of Commons floor) and 227 (the House

of Peers floor), represent, in particular, the extreme diffusion in the floor of the House of Commons, compared with that in the House of Peers, the dotted surface and the dotted lines indicating the porous surface at which the air enters.

657. Figs. 228 and 229 represent a plan and section, illustrative of the ventilation of the throne. It is ventilated by

Fig. 228.

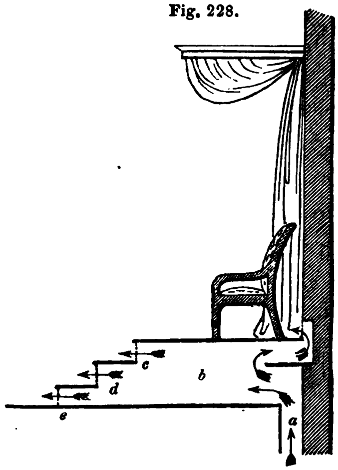
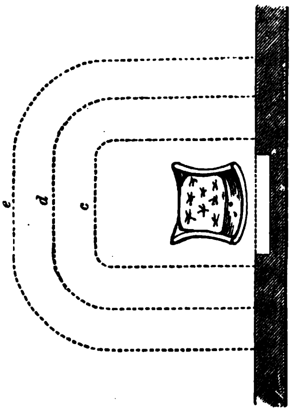


Fig. 229.



special arrangements, controlled at the air-channel *a*, which supplies the chamber *b*, from which the fresh air is diffused around the chair at *c*, *d*, *e*, or other places.

658. The following extracts from the evidence laid before a committee of the House of Peers, appointed in reference to the New Houses of Parliament, explain the leading differences between the ventilation of the House of Peers and that of the House of Commons :—

"With respect to what was done under these circumstances, having stated at the commencement the difficulties of the subject considering the means placed at my disposal, I mentioned that I could make openings for letting out air, and openings for letting in air, with such diffusion as the grant permitted. It did not permit me to give a floor, such as was given in the House of Commons. At present, the complaints that have been made refer principally to two circumstances, as far as I have traced them. In the first place, they refer to the admission of air behind the back; that can be entirely stopped, whenever it is wished, and air admitted by the bar, and under each individual seat, in greater quantity than is done at present. I have repeatedly, during this very session, been present in the House of Peers, when numbers have left it, some because it was too hot, and some because it was too cold, at the same moment; and I have stated, that our great difficulty is, that members of that House do not tell us, so frequently as is desirable, when they find too little air coming in, or too much. I have been there, under circumstances, when we have been quite at a loss how to proceed from the great diversity of opinion entertained by different members, and sometimes for three or four weeks successively, no communication is made upon the subject. We have the power of shutting off entirely all ingress of air, or of increasing gradually to any extent, till we arrive at the highest power we can command; but it is rarely that communications are made to us.

"I have never yet, so far as I am aware, been called upon to remedy a complaint that was not remedied immediately, when no incompatible demands were made at the same moment by other parties, which necessarily restricted the extent of the alterations that might have been made to accommodate these

demands. I must except, however, the local influence of cold glass, where the protection of double windows is not given; and the effect produced by air from cold or unventilated lobbies, when the doors are not sufficiently closed to afford protection against them. I also know, that individuals have stated that they have remained for a whole evening uncomfortable, without even telling us, though there was a person stationed in the House for this purpose. I believe the committee will find, that, with these exceptions, no complaint has been made which could not have been immediately removed, though it is impossible to attempt to obviate individual complaints by diminishing the ingress of air at particular places, without reducing the general supply of air, or increasing the currents in one place as they are diminished in another."

I need scarcely add, that I do not here refer to impurities in the external atmosphere, which, as explained in another place, are often, from their magnitude, altogether beyond control, except by the action of special chemicals, which are resorted to as rarely as possible.

CHAPTER II.

REMARKS ON THE VENTILATION OF THE HOUSE OF COMMONS.

In directing the ventilation, great difficulty is often experienced in ascertaining the feelings of the members. They necessarily fluctuate with every change of circumstances in the state of the internal or external atmosphere that is not immediately controlled, independent of the extreme diversity of temperament that may be expected to prevail where so many are assembled in the same apartment. The first remark made after the House of Commons met, subsequent to the alterations, was,—" The temperature was rising, we shall be suffocated immediately." This was addressed to me by a member walking from the bar to the door, and he had no sooner passed than another followed him, hurriedly stating as he passed, " I am shivering with cold, I can bear this house no longer." I went to the lobby and stated to each what the other had said, when a conversation ensued as to the most desirable temperature, as it was obvious, that, unless a peculiar atmosphere were prepared at each place, it would be impossible to do more than give an average quality, particularly when some members demanded a temperature of 52°, while others required a temperature of 71°.

659. The House is heated to 62° before it is opened, and maintained in general at a temperature between 63° and 70°, according to the velocity with which the air is permitted to pass through the House.

660. This velocity is necessarily regulated by the numbers resent on a given space, the temperature to which the air can reduced in warm weather, and the amount of moisture which

it may contain, when the quantity may be excessive. Some members are much more affected by an excess or deficiency of moisture, than by alterations of temperature.

661. In extremely warm weather, the walls sometimes attain a still higher temperature, but by increasing the velocity, air even at 75° may be rendered cool and pleasant to the feelings. Much is frequently effected in cooling the House in summer by drawing cold air through it during the night time after the members have retired, by the evaporation of water, by the contact of air with cold water apparatus,* and, in rare cases, by the use of ice; but no mode is more capable of regulation, so economical, and so readily available, as a variation of velocity. The more marked movement of the atmosphere which increased velocity renders necessary, should prevent it from being resorted to in a greater degree than may be absolutely essential.

662. Attendants on the ventilation take the temperature periodically during the sittings, and are constantly ready to receive instructions as to the alterations required when they may not have anticipated them, though this they are in general enabled to effect. But as no one can ever be an exact judge of another's feelings, and from the great diversity of requests at times communicated to them, and the fact that extreme constitutions are necessarily most prone to demand changes, while their indications are less likely to conduce to the general comfort, it is not unfrequently difficult for them to decide as to complaints; communications, therefore, as to the ventilation, are usually addressed to the Sergeant-at-Arms, whose knowledge of the general expression of opinion is always a safer guide than that of individual members. In some cases, where the debates in both Houses have continued for a long period, and the fluctuations have been great both in the state of the weather and of the numbers attending, I have occasionally, in studying details as to the action of the ventilation, made, with advantage, from 50 to 100 variations in the quantity or quality of the air supplied in a single

* The same that is used as hot-water apparatus in cold weather.

night. It is only by constant examination of the state of the atmosphere in different parts of the House, and especially by noting the effect produced by local aggregations, which always determine peculiar eddies, that the demands made can be met with that average supply and quality of air, which is alone practicable in a public assembly.

663. Fluctuations, indeed, are sometimes so frequent, and to so great an extent, that the attendants cannot give the average approximation of which the apparatus is susceptible, unless they are perpetually directing their attention to the passing changes in the same manner as a sailor steering a ship.

664. Since the alterations were made in 1836, the atmosphere with which the Right Honourable the Speaker is supplied, has been placed under special control. Before this was done, it was impossible to give the kind of atmosphere generally desirable in the House, and, at the same time, to meet the very different circumstances which always require attention in a case where the peculiar duties, and a sitting extending so frequently to ten or twelve hours, or to a longer period, necessarily demand special modifications. The same has been done, also, in respect to that provided for the Sergeant-at-Arms.

665. Some constitutions differ so much from others, in respect to the air which is most suitable for them, and are so much affected by variations in the temperature and moisture of the air that may be almost inappreciable by others, that, where it may be requested, I have certainly been led to entertain the opinion, that any member who may have specially to address the House, should have some preference at least, in controlling the temperature and the ventilation when he is so engaged.

666. The temperature may always be advantageously increased, and the velocity diminished, before the usual dinner hour.

667. After dinner, other circumstances being the same, the temperature should be diminished, the velocity increased, and the amount of moisture in the air reduced, when practicable.

668. During late debates, as they advance to two, three, r, and five in the morning, the temperature should be gradually

increased as the constitution becomes more exhausted, except in cases where the excitement is extreme.

669. The atmosphere in the House of Commons never being quiescent for a moment, the effect produced by it is very considerable on a constitution accustomed to air comparatively stagnant. It sustains a continuous evaporation, both from the lungs and from the surface of the body; and no cold currents descending from the windows, coughing has almost entirely disappeared, compared with the extent to which it has sometimes been observed, before the present system was introduced.

670. The condition of the atmosphere which is sustained being known, were the nature of the clothing, more particularly for the feet, not to be so dissimilar as it sometimes is, a greater degree of unity would prevail as to the state of the air demanded.

671. Those who have been recently riding, dining, or engaging in any exercise, and whose circulation is accelerated, feel a medium atmosphere too warm. On the other hand, after a cold drive in a carriage, the temperature cannot be raised too high till the constitution shall have been warmed, as it were, to an average standard. In an extreme case, during the severe winter that occurred in 1840-41, several members having entered the House of Peers after being very much chilled, incessant demands were made for more and more warmth, and the temperature was at last brought to 74°. But even this was not sufficient, and I accordingly suspended the ventilation entirely, and kept the air as quiescent as possible, till the effects of the excessive external cold had passed away. Members who have come down to the House of Commons unwell, have occasionally been relieved by exposing themselves, for a short time, to a blast of hot, cold, or tempered air in the air channels.

672. When a great fall takes place in the barometer, the drains, the river, and the surface of the ground often exhale bad air to such an extent, that the entire atmosphere, on every side of the houses, is loaded with impurities.

673. Gas-liquor on the surface of the river is an occasional source of offence. I noticed it, at times, covering the surface of

the water for nearly a mile in length, and floating past the Houses of Parliament. It is familiarly known to the watermen by the name of Blue-Billy. Emanations from the grave-yard at St Margaret's Church are occasionally very offensive. They have been the subject of complaint more especially by members attending the committee rooms opposite. Of seven different individuals whom I requested to inform me of any emanations which they might perceive arising from the grave-yard, one stated that he had never noticed any thing offensive, though he had passed through it almost daily for years. The second stated, that at one period, for about a month during the summer, the emanations were very offensive. Four others noticed them frequently. The last, who is at present engaged at the Houses of Parliament, has noticed them repeatedly. On one occasion, he informed me that he suffered severely from headache and sickness for several days, after passing through this churchyard. Its effects caused him to lie down several times in the afternoon, and he was unable to take his usual refreshment. He had not, consequently, passed through it since, preferring to go round about for the last several months.

The smell from gas-works on both sides of the river occasionally affects the atmosphere on every side of the House.

The entire surface of the street has occasionally been found to present a surface of decomposing impurities not capable of being easily controlled but by the action of lime-water.

In calm weather, the smell of tobacco occasionally accumulates in the neighbourhood. On one occasion, about 50 coachmen were counted smoking at the same time.

674. When a dense fog arises from the river, and becomes visible in the House, it is difficult to dissolve it except by the action of excessive heat. The very varied electrical condition of the fog appears to produce some singular peculiarities affecting the means required for its solution.

675. In some cases, where the most extreme complaints have been made, as to the state of the atmosphere, they have been traced to barges laden with manure, to drains exposed during

the progress of the works of the New Houses, and to the state of the atmosphere in places in the vicinity, particularly when cleansing operations have been carried on there, at times when the Houses were sitting.

676. Many other causes, also, have frequently given rise to complaints on the state of the atmosphere in the Houses, particularly the smell from the kitchen chimneys, when the products are involved externally by the action of the wind in local eddies, half-extinguished lamps, naphtha used in experiments on lighting, chimneys on fire in the vicinity, &c. &c.; all of which were usually placed, at first, to the credit of the ventilation.

677. In meeting these various contingencies, and others which it would be almost endless to specify, arrangements were made to take the air from different sides of the House, and, occasionally where neither heat, filtration, or washing the air, have been sufficient to prevent discomfort, very minute quantities of chlorine and other chemicals, particularly nitrous acid, where exhalations from animal and vegetable matter have predominated, and ammonia and lime when the amount of carbonic acid in the external atmosphere was extreme, have been used. The rare occasions, and the minute quantities in which some of these were employed, do not permit me to refer to them as matters in habitual use.

678. Since the river front has been built up at the New Houses, it has diminished very considerably the effect of smoke from steam-boats on the river upon the present Houses.

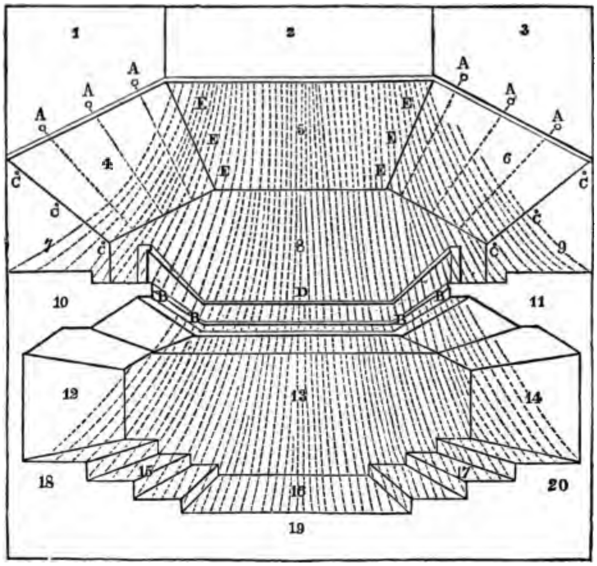
679. In both Houses, some seats are necessarily very different from others. In the galleries, in particular, constitutions extremely sensitive as to the influence of heat, though supplied with fresh air through the air channels in the wall, experience the influence of radiations from the lamps; an increased amount of ventilation counteracts the effect they produce.

CHAPTER III.

INTRODUCTION OF GAS AT THE HOUSE OF COMMONS.

680. In the first experiments, conducted under my direction at the House of Commons, ventilation and the communication of sound were the only points to which my attention was directed by the committee, arrangements having been made, at the same time, for removing directly all the products of combustion from the candles, by giving the air throughout the whole House the inclination repre-

Fig. 230.



the accompanying figure* (230). The air proceeds from

* is again mentioned in a subsequent paragraph in this chapter.

the floor, both of the body of the House and of the gallery, as the dotted lines indicate. Some statements appear in the report on the lighting of the House, of some experiments made by Mr Gurney and Mr Bellamy, in which a recoil of smoke from the ceiling is described as having ensued on some gunpowder being exploded below, and the ventilation is said to have been, at the time, in its usual condition. But, surely, the effect of an explosive production of smoke is no test of the ordinary movement of a ventilated atmosphere, while, on the other hand, the ordinary condition of the ventilation is as variable as the time of the year, the numbers in the House, and the period of the sitting; particularly as adapted to a daylight sitting, or to the evening after the lamps or candles are lighted. And unless the precise state of the ventilation were explained, the mere statement that it was in its ordinary condition has no determinate signification. I have adverted to this circumstance, as it has been frequently referred to, and as I have had no previous opportunity of explaining it.

681. Before Sir Frederick Trench's experiments, and those with the bude-light, were commenced, a question was put to me as to the introduction of gas at the House of Commons; and after having stated my strong conviction of the importance of this step, two objections were urged as to a scheme I gave for introducing it, so as to avoid the prejudice against it: these were, first, that a sufficient body of light could not be introduced through the glass, if the lights were placed externally; and, secondly, that offensive shadows would appear on the floor. I requested a day to shew an experiment in answer to these objections, and in about twenty-three hours from the time permission was given, the gas was introduced into the House of Commons, and six rows of perforated pipes adjusted over the glass, as shewn at A A A A A A, Fig. 230. The result of this experiment having proved that the objections referred to were obviated, the next step I took was to recommend the introduction of proper burners as a substitute for the mere flickering jets, some thousands of which were obtained simply by piercing the tubes within the very short period mentioned.

This, however, was not done, and the gas apparatus was used with those flickering lights for some time after the commencement of the session. Accordingly, in reply to a letter from Sir Frederick Trench to the Right Hon. the Viscount Duncannon, which I was requested to attend to, I stated the circumstances under which the first gas experiment had been made, and also explained the system of gas lighting adopted in the experimental room constructed at Edinburgh, in reference to the House of Commons, in which many of those arrangements for ventilating gas burners were introduced, such as have been particularly described in patents subsequently taken out (in some of which, however, the character of the burner used formed the leading object), though they are illustrated by diagrams, both in my Outlines of the Ventilation of the House of Commons, of which 2000 copies were distributed seven years ago, and in the letter of which I have spoken. The following diagrams illustrate the experiments on exclusive lighting which have been mentioned.

682. Figs. 231, 232, 233, represent the exclusive lighting adopted in the experimental apartment, when a Gothic pendant, having an illuminated drop, was used. The drop came sufficiently low to allow the ceiling to be illuminated; and while the vitiated air was removed directly from the lamp to the ventilating channels, as shewn in Fig. 232, the atmosphere generally throughout the apartment was made to pass from the ceiling *c c* to the floor, or reversed, and made to move from *d* to *c*, according to the trials which were required. The great advantage of the Gothic pendant consisted principally in the extreme facility which it afforded for surrounding the hot-gas ventilating pipe with non-conductors, and also with currents of cold air, so as to exclude from the apartment all that radiant or conducted heat above the visible light, which a naked tube is apt to communicate where a strong light is used. Four pendants were commonly lighted, but two were sufficient for ordi-
y purposes. It will be obvious, that, in some buildings, few
s would be more practically useful and agreeable than a

Fig. 231.

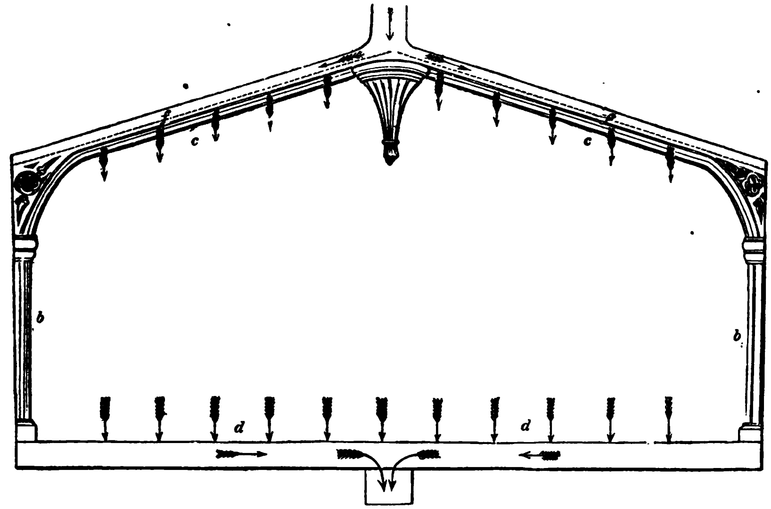


Fig. 232.

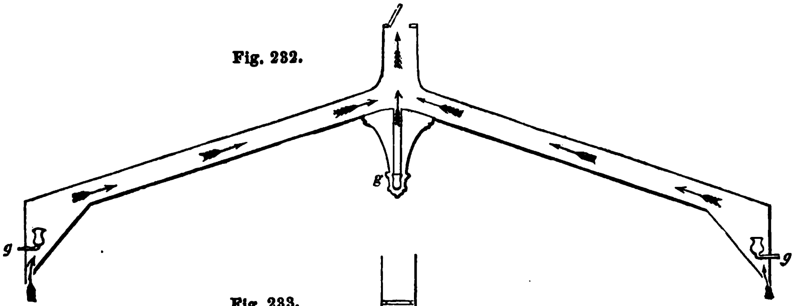
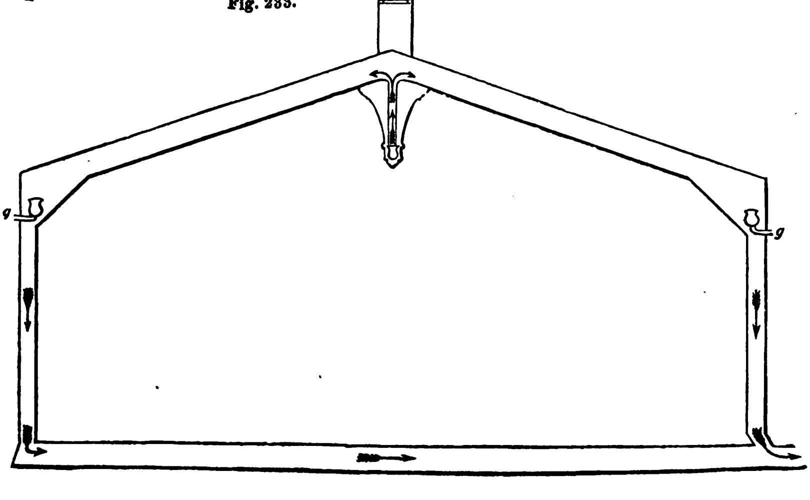


Fig. 233.

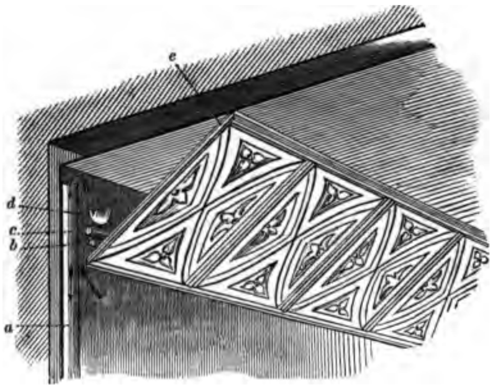


series of gothic pendants with illuminated drops, appearing like stars diffused over the ceiling.

683. By the arrangements adopted, the products of combustion could be drawn down in cold weather through iron pillars concealed at *b b*, so as to impart a mild and equal heat to the apartment, being afterwards led away under ground to the ventilating shaft, as represented in fig. 233.

684. Fig. 234 represents another system of illumination tried in the same apartment, and equally exclusive, the pro-

Fig. 234.



ducts of combustion having been carried away by descent through a concealed ventilating pipe *a*. The carrier tube explained in the next paragraph is indicated by *b*; *c* is the gas-pipe for the permanent light, which was obtained from upwards of sixty patent jets, one of which is seen at *d*. The light passed through obscured, painted, tinted, or figured glass, at *e*, according to the varied arrangements made in experimenting with an illuminated cornice, which extended all round the room.

685. Fig. 235 gives a view of the carrier tube *a*, and the permanent light tube *b*, with some of the attached burners *c c c*. The carrier burner having been kindled in the centre at one side (between the two arrows, Fig. 236, turned from each), the light flashed along the cornice till the two streams the opposite side; and having kindled the various bur-

ners attached to the second tube, the lights of the carrier burner were at once extinguished. A little leakage was of no con-

Fig. 235.

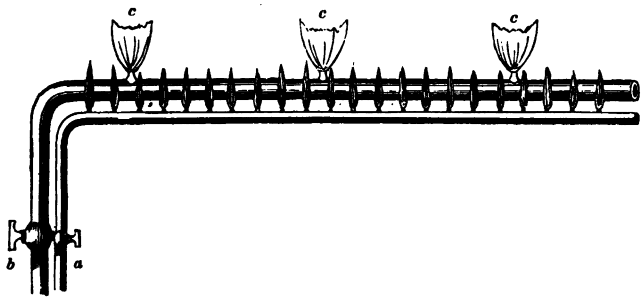
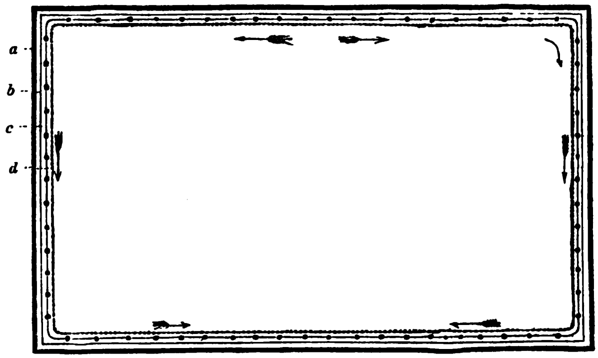


Fig. 236.



sequence, as the whole of the gas-apparatus, whether in use or not, was continually subjected to the action of a ventilating power, which equally removed the products of combustion, and any portion of unconsumed gas, whether the apparatus was lighted or not.

686. Fig. 237 represents another variety of exclusive lighting, fresh air being supplied to the apartment by a porous surface from *a*, and the vitiated air from the lamps above *g g* mingling with the air from the apartment, and being discharged by the central ventilating aperture.

687. After the experiments were shewn with the pendants and illuminated cornices, numerous places were fitted up in the

same manner; and in many shops in particular, where the

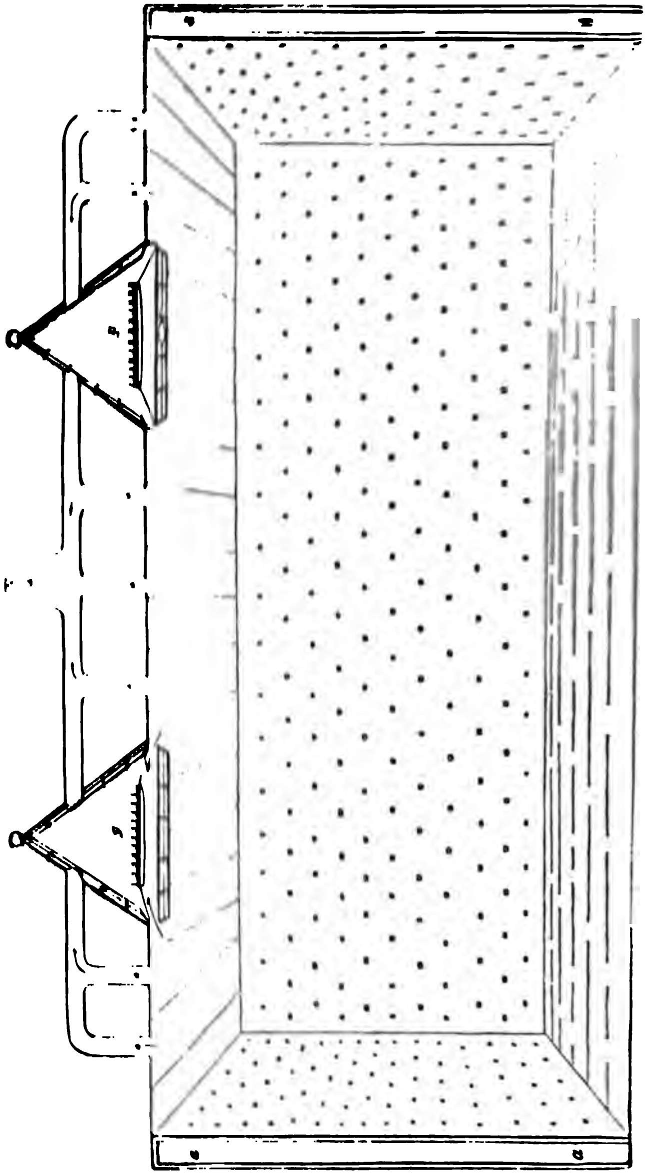


Fig. 31.

health of the inmates suffered from the carbonic acid and moisture, as seriously as the goods kept for sale, a great diminution

the deterioration of exposed goods always accompanied the proved health of the inmates.

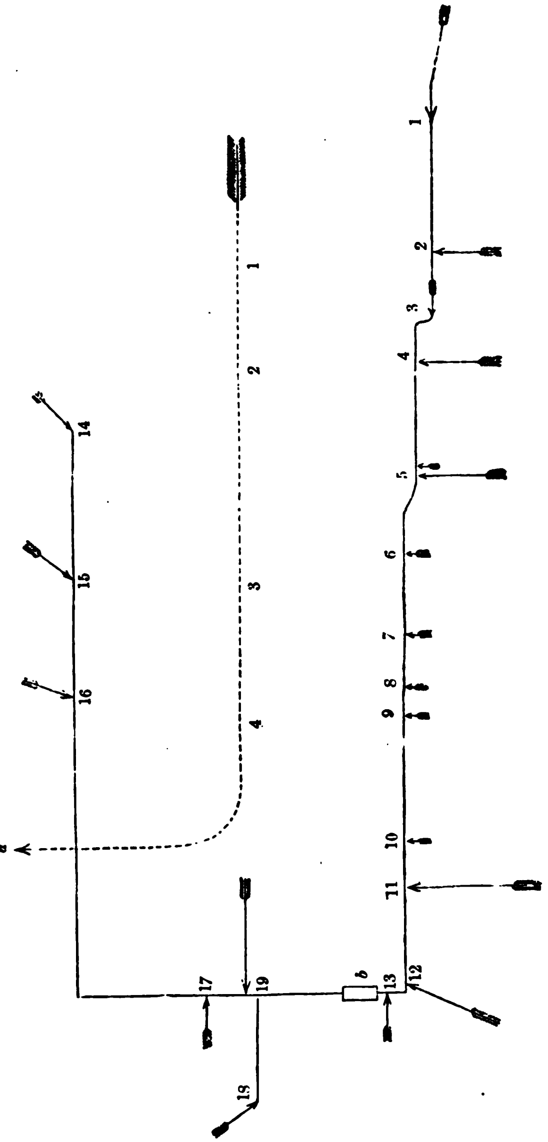


Fig. 238.

688. The gas-burners used by Mr Gurney are controlled by ie following scheme, Fig. 238, which I adopted in connection

with the lights now in use, excepting the four that play into the great ventilator, indicated by *a*, immediately above the ceiling, which afforded a ready egress for the products from the rest, along with the air from the House itself. A gas ventilating shaft was raised at *b*, and leading lines of communication established on either side of the House, and with the lobbies, while smaller channels conveyed the products of combustion from the individual burners to them, each being regulated by a valve, so that the power placed upon it might not interfere too much with the combustion at the burners. These arrangements have not only secured the effective ventilation of the gas-burner on the exclusive principle, but also prevented the interference of external currents when the wind was violent.

689. Having adverted in this chapter to various circumstances which I considered it necessary to mention in answer to numerous questions often put to me in connection with my experiments at Edinburgh, and the first trial made under my direction with gas at the House of Commons, when I only spent a day in London for this purpose, I cannot allow this opportunity to pass without also stating, that, though I have been always partial to the exhibition of the naked light with a well-defined edge, unless the obscuration of the glass, which may conceal this, be so entire as to leave no visible indication of the site which it may ; I have witnessed Mr Gurney's experiments with much re, and gladly bear testimony to the step which his im- d burner has made in facilitating the more general intro- n of gas for public purposes, whenever a central burner of power may be required.

590. In considering the general question of artificial illumi- ation, not induced by a diffused light with invisible burners, and imitating, accordingly, the light of day, it will be observed that the House of Commons presents those peculiar difficulties that all buildings with galleries must have. The light above st be powerful to illuminate the floor, even if the whole cham- 2, and 3 (see Fig. 226), be illuminated; and thus it may in the galleries, 7, 8, 9, though shining equally

through 4, 5, and 6. If placed at D, to illuminate equally the ceiling and floor, the heat as well as light begins to operate on the galleries. If lights be placed at B, B, the products of combustion being withdrawn directly through the cavities 10 and 11, but by metallic pipes enclosed in a series of wider pipes, no heat could be conveyed to the galleries. If currents were constantly made to pass outwards between the various external cases, they would amply satisfy the demands of the body and floor of the House, 12, 13, 14, 15, 16, 17, while another series, placed at C, C, C, would be sufficient for the galleries. (The equalizing chamber is indicated by 18, 19, 20, below the floor.) From these circumstances, it will be readily seen that it is impossible to have the system of lighting introduced in such an apartment on the best footing, and that comparative advantages and disadvantages must attend any arrangements that may be adopted, where local circumstances, and particularly the necessity of approximating numbers within a given space, render galleries indispensable.

CHAPTER IV.

COMMUNICATION OF SOUND.

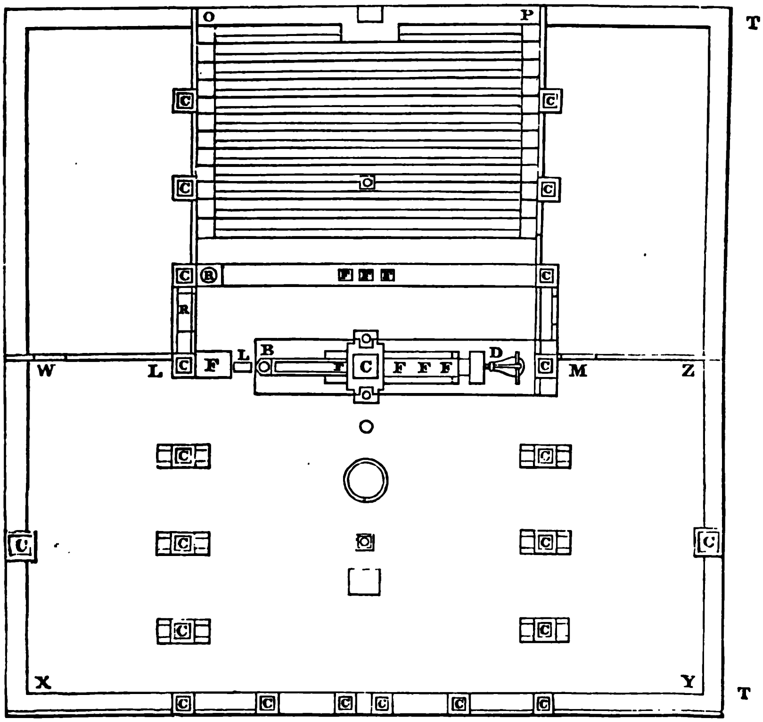
691. There are, perhaps, few, except public speakers and singers, who are led to consider the extent to which the respiration of those that speak or sing is affected by the facility with which sound may be communicated in different buildings. All those whose engagements lead them to exercise their voice much in public, are, in general, well aware, that in some rooms there is comparatively little effort required to render it distinctly audible; while in others, the system is soon as much exhausted by the laborious efforts that are necessary for this purpose, as the attention is distracted by the forced exertion and peculiar emphasis or cadences with which it may be requisite to speak, in order that they may be understood.

692. The difficult communication of sound in any building is a grievous tax upon the strength, the time, and the attention of any public speaker, and if not the actual cause of death in some cases, where a great exertion had to be often made beyond the powers of the constitution, has at least too often assisted its premature arrival, by the extent to which it undermined the constitution.

693. My attention was more especially directed to this question, in consequence of having had to address students, at one period, for seven and eight hours daily, in successive classes, where the interruption occasioned by the endless variety of experiments performed by medical students, officers going abroad, agriculturists, engineers, emigrants, manufacturers, and others, occupied at the same time, necessarily engaged a severe and

varied action of the voice, in giving directions from time to time, to prevent accident, as well as in the demonstrations given every hour, and in calling the attention of all present to the progress of individual experiments when they became most interesting and instructive. In the class-room I built in 1833, it was stated by every individual almost who visited it while in progress, and who adverted to the subject, that I never would be heard, and warnings and recommendations were constantly brought forward as to the absolute necessity of altering it. I depended, however, on a low and reflecting roof, on the reduction of the walls to the

Fig. 239.



lowest altitude compatible with the wants of the place, and on the absorbing nature of a rough and inelastic floor, made of an

earthy composition, such as allowed that freedom which was necessary where so many furnace operations were conducted.

694. Fig. 239 indicates generally the leading features of the class-room, which is nearly 80 feet square, exclusive of contiguous apartments not represented. The quadrangular space F O P D indicates the lecture-room, which was seated for 300, a range of low furnaces extending from the engine and blast-furnace F L B, to the forge D, and the lecture table before it, which was 40 feet long, having a boiler at one end, and descending furnaces and ventilators F F F in the centre. The larger area W X Y Z formed the practical class-room. The roof of the whole was supported partly on the walls, and partly on twenty-three chimneys C C C C, &c. The practical class-room communicated freely with the lecture-room above the central furnaces, except where the central chimney C rose to the roof. Some of the chimneys have not yet been brought into use; others commanded various ventilating flues and furnaces. The central chimney commanded twenty-two leading communications, part only being occupied at the same time.

695. Fig. 240 gives a transverse section to a larger scale through the lecture-room and practical class-room, in which the descending ventilating flues are represented. Figs. 49, 50, page 99, shew the detailed arrangements, in connection with those flues.

696. It may be sufficient here to state, that in every part both of the lecture-room and of the practical class-room, whether crowded or empty, the slightest whisper or the loudest noise was heard distinctly without offensive reverberation, or the necessity of any exertion of the voice beyond that used in conversation. I believe I am correct in stating, that numerous members of both Houses of Parliament, who visited this class-room, were of the same opinion; among whom I may refer to the Right Hon. Earl Grey, the Marquis of Tweeddale, Lord Brougham, and Lord Campbell. In one of the trials made by Lord Brougham, his lordship having stationed himself in the gallery near O, I placed myself

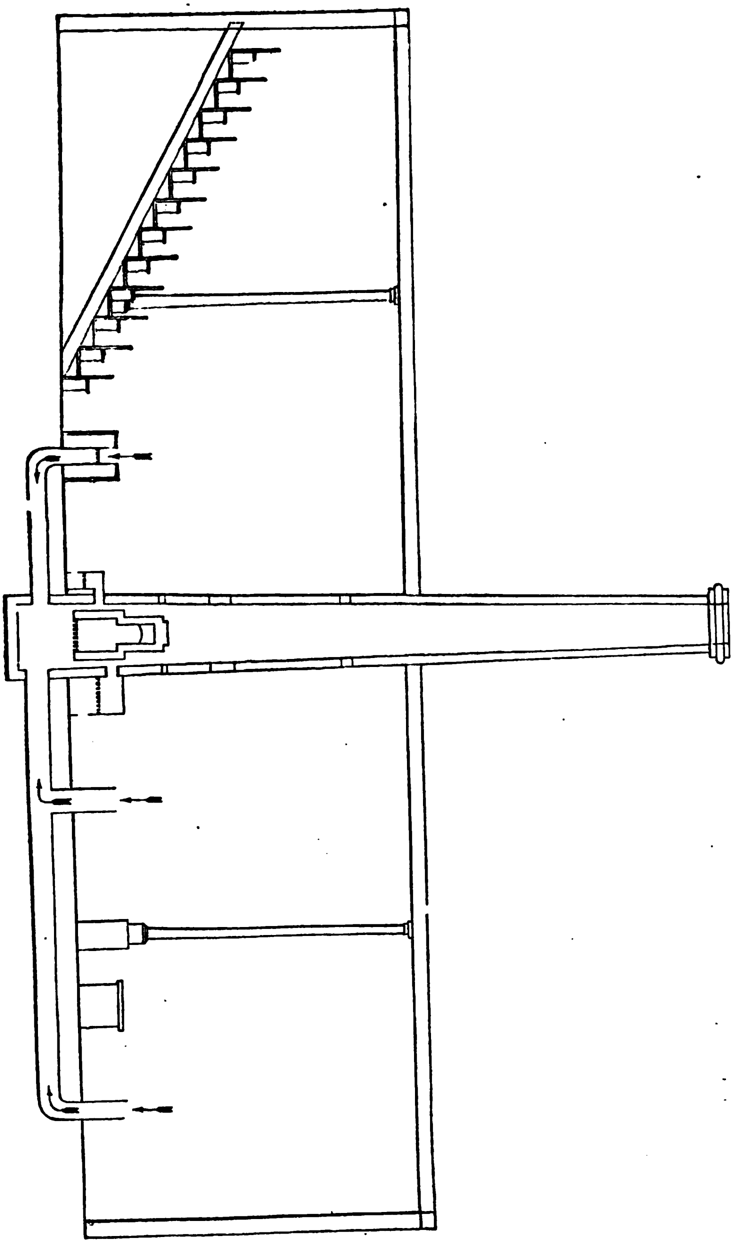


Fig. 240.

as near as I could to the corner W, accompanied by Lord Murray and Lord Moncrieff, and, speaking in a whisper, or in a low conversational tone, every word was heard, though I was out of sight at W, and afterwards, whether I was out of sight or in sight, in walking round the various chimneys C C C C C C, in the practical class-room. At that period, the spaces on either side of the lecture-room were excluded from all connection with the practical class-rooms; that opposite W L formed the area in which the various experiments were conducted afterwards in the apartment constructed in reference to the ventilation and lighting of the House of Commons.

697. Having explained the principal features of the apartment whose construction led to my being called before the committee on acoustics and ventilation, I shall now state briefly the peculiarities in the communication of sound in the present House of Commons, as compared with the condition in which it was when my attention was directed to it.

698. At that period, the following were the principal causes of the defective communication of sound:—

1. The great altitude of the ceiling, and the large space which the voice had consequently to fill,—a circumstance at all times aportant, but more particularly so where it is necessary that ne voice should prevail over the hum of conversation that may be generally observed. Where absolute silence is maintained, mere altitude is of less importance, as the human voice can fill an immense space with distinctness where no interruptory reverberations destroy distinctness of intonation.

2. The soft and yielding canvas with which the walls and ceiling were covered, impaired too much the support which the voice should receive.

3. The amount of noise that entered by the windows at all imes, and particularly when opened for ventilation, was ex-. On some occasions I shewed, as explained at the time mmittee, that the vitiated air from the House of Peers by the reporters' gallery, to the House of Commons

during easterly winds; while, with a west wind, other circumstances being similar, the vitiated air from the House of Commons passed to the House of Peers. In the same manner, though no individual sounds were audible, noise from the one house not unfrequently contributed to add to the indistinctness of sound in the other. Independently of this, however, the noise of coaches, cabs, and omnibuses, of the letter-carrier's bell, and every other noise produced in Old Palace Yard, gained more or less access to the House of Commons.

4. The carpet or floor-cloth, which had been adopted on account of the rapidity with which all others had been worn away, produced very considerable noise as the members passed.

5. The locking and opening of the door proved also a continued source of interruption.

6. A current of hot air, rising in a broad sheet along the centre of the House, refracted the sound passing from side to side, and rendered the intonation indistinct; one of the members of the committee, when I explained this circumstance, stated that he had often noticed that he could not hear a member opposite him distinctly, at particular times, unless he shifted his seat along the bench; and on examining the place he referred to, it was found that he had moved to a position where the hot current no longer passed between him and the member speaking.

699. In the present House, the following are the leading circumstances that may be observed in respect to the communication of sound:—

1. The lowering of the ceiling, as shewn in previous figures of the House of Commons, cut off a large portion of superfluous space, rendering, accordingly, the amount of voice necessary to fill the House much less than formerly; and though the noise of conversation was, at first, proportionally increased, the experience of the several sessions which have passed has led me to believe, as I had previously anticipated, that, after a short time, the strength of tone adopted for conversation would be less, as the members became practically familiar with the power of the House in communicating sound, except when resorted to for the

purpose of interruption. A less proportional effort than formerly is now sufficient, on the part of a speaker, to enable his voice to be heard distinctly above any ordinary and moderate noise from conversation.

2. The resilient influence of the reflecting glass and wood above the galleries, and of the inclined pannels under the galleries and above the floor, gives a sustaining power equally to the voice and to the ear, and contributes, therefore, to the same effect as the lowering of the ceiling.

3. The freedom with which an impulse, once produced and inclined across the audience, escapes, both by the porous floor and by the central ceiling, throughout its whole extent, prevents all offensive reverberation, and discharges immediately the remaining sound of every syllable as it is pronounced, leaving, accordingly, a free course for the full, effective, and uninterrupted action of each succeeding syllable. Few persons are aware of the great extent to which distinctness and purity of intonations are sustained in this manner; but the amount of sound discharged in this way will be better understood when it is mentioned, that almost every member who speaks in a moderately loud tone can be heard distinctly in the air-chambers, both above and below the House; while those who speak in a louder tone can be recognised, after the sound has passed the pannels in the ceiling, the ventilating valve, moved along the roof, descended the tunnel outside the libraries, and reached the base of the ventilating shaft, a distance of nearly 200 feet from the Speaker's chair. Members who speak both loudly and very distinctly, can be understood there, in general, when the House is silent.

700. It is scarcely necessary to add, that this freedom of escape for the excess of sound, diminished to a certain extent the gain obtained by the lowering of the ceiling; but this was more than compensated by the employment of powerful reflecting surfaces, which, while they strengthen the first impulse of sound, as it passes across the ear, throw it immediately afterwards where it is discharged, and prevented from affording any interruption to each succeeding sound.

4. The comparative unity of temperature and movement of air through the House, also facilitates unity and distinctness of intonation. This was at its maximum during the short period when the House was lighted with gas, in the absolutely exclusive manner formerly described.

5. The soft, thick, porous, and elastic hair-cloth carpet allows all necessary communication from place to place to proceed without producing any noise, while it is perfectly pervious to the excess of sound which escapes through it to the air-chambers below.

6. The double windows, which have not been opened once during the last seven years, and the mode by which the air enters and escapes from the House, have effectually excluded the great interruption formerly caused by noise from without.

701. Though the nature of this work prevents me from entering more minutely into the question of the communication of sound at the House of Commons, I add the following summary, which may be useful to those interested in the communication of sound in public buildings.

1. Sound is sustained for the longest period in air-tight apartments having powerful reflecting surfaces, if the sound be produced, or the apartments constructed so that the various impulses successively communicated to the air shall not extinguish or neutralize each other.

2. With a moderate impulse, most apartments simply reflect the sound that falls upon the roof or walls; but there are cases where the roof or other parts of the building have been thrown into vibration, and augmented greatly the amount of sound produced, but not in general with any advantage to distinctness and purity of intonation.

3. Every apartment has a key-note or intonation peculiar to itself, and when a musical ear ascertains this, and adapts the song or speech accordingly, the voice sounds more harmonious, and less effort is required to sustain it, or to become sensible of it, in listening to its effect.

4. In rooms lined with sonorous metals, the slightest effort

of the voice is heard with extreme distinctness, and to many with a keenness and intensity which is painful, unless the sound be very subdued. The effect is proportional to the sonorous nature of the metal employed. In metallic tubes of considerable size, the sound may be conveyed for miles. The duration of the sound in small apartments lined with metals and rendered air-tight is also considerable. In a lead chamber at Montrose, which had been constructed for the preparation of sulphuric acid, 80 feet long, 20 broad, and 12 high, I made a number of experiments with the assistance of Mr Foote, the proprietor, and Mr Carnegie of Craigo, and found that any sound produced in it continued in general for seven or eight seconds after the impulse which had given rise to it had ceased. In the interior of one of Barclay and Perkins' boilers, sound produced in the same way continued for eight seconds.

In many apartments, I have noticed, in this country and abroad, the sound has continued from eight to ten seconds very distinctly audible. In one of the principal apartments of one of the palaces near St Petersburgh, the reverberation produced by stamping the foot once upon the floor continued for twelve seconds.

702. It will be obvious that, in apartments where sound is reverberated, re-echoed or sustained for so long a period after the primary impulse which may have produced it shall have ceased, it must interfere extremely with distinctness of speech. A speaker enunciating two, three, four, or five syllables in a second, will, in the latter case, have spoken the thirty-fifth before the sound or confusing influence of the first may have passed away, in a room that reverberates for seven seconds.

703. In some rooms, a singular twittering noise succeeds any sudden sound produced in them, and continues in them for a considerable time. The most marked apartment I have seen in this country in which this can be observed, is Almack's Ball Room (Willis' Rooms, St James). The room adverted to in par. 701, presents the same peculiarity.

704. If secondary reverberations be considerable in any

apartment, while a primary tone is still sustained by any one continuing to speak, and if a door be opened through which the sound can escape freely, it sometimes is observed that the voice may be more distinctly followed without than within,—the primary sound alone extending to any distance beyond the walls, while the minor sounds are lost before they can proceed so far.

705. Proximity to a reflecting surface is always favourable both to the speaker and hearer, unless the discharge or absorption of excess of sound be insufficient.

706. A room may be very unfit for clear and distinct intonation when empty, which is excellent for music or speaking when full,—the soft clothing of an audience, as well as the destruction of the reflecting power of the floor by the number congregated, diminishing excessive reverberation. Public singers have often been heard to state that they could not command their voice well in empty rooms,—an observation which has at times been attributed to the effect of disappointment upon their spirits; but, whatever influence that may have produced, the physical effect of a crowd in destroying excessive sound must also be taken into consideration. A reflector exactly opposite a speaker may be powerful in sustaining sound when near; but when beyond a certain distance, occasionally the sound is returned offensively upon the mouth, and interrupts the speaking of those who are sensitive to the impulse of sound.

707. Hitherto, plain reflectors have alone been adverted to. Parabolic and other curved reflectors are certainly powerful in distributing sound, when the voice proceeds from a proper site; but they are not so advantageous as might be at first anticipated, in consequence of their collecting sound which is reflected upon the ear of the speaker, as much as they discharge sound. To many this proves so annoying that they soon give up the parabolic reflector, however much they may otherwise approve of it. Some individuals, however, by long habit, appear to get over the difficulty that arises from the extent to

which the speaker is too often annoyed by the return of his own words to the point from which they proceed.

708. Where an apartment presents successive reflecting surfaces, a series of notes sung by one person at proper intervals, returns in full and harmonious concord upon the ear, as if a number of voices were uniting together to produce the successive chords that are heard. In no place is this effect more beautifully observed than from the whispering gallery of St Paul's.

709. In many schools the amount of reverberation is so great, that it impedes seriously the business of the school. They sound, when empty, like a drum, and the numbers that cover the floor are rarely sufficient to destroy the reverberation to the extent required. At the National School, for example, the sound was extreme, and the defects complained of having been found to arise principally from the cause now mentioned, the plaster of the ceiling was removed, but the ceiling joists left. No prolonged reflection can now be sustained between the floor and the roof, and the excessive noise that formerly prevailed has been much reduced.

710. In many halls and galleries with arched roofs or domed ceilings, the amount of interruption caused by the curved surface is always contingent upon the form of the curve, upon the nature of the material, of which the reflecting surface is composed, and the distance of the hearer from the curve. If he be in the focus, the resonance will prove offensive in general; but if the floor on which he stands, or his ear be at a distance from it, whether above or below the focus, the sound will be more or less equal or pleasing, according as its intensity is more or less uniform throughout the whole apartment.

711. There are few large places of ordinary construction in which the intensity of sound is not very unequal in different parts of the same room. In the Hal au blé, at Paris, any person speaking under the centre of the dome, feels immediately the force with which the sound is concentrated and returned. In the Gallery of Statues at the Louvre, two large vases, at a

distance of about 85 feet from each other on the floor, are so powerful—in conjunction with the arched roof—in discharging and concentrating sound, that any two individuals speaking and listening at their foci, can carry on a conversation with each other, though hundreds in the intervening space cannot hear a word which they may exchange. I have to thank his Excellency Count Flauhault for the assistance he afforded me in numerous experiments on the communication of sound that were made in the different apartments of the Louvre.

712. In an apartment in the city, where the sound from the roof was excessive, and so annoying that it proved a complete interruption to business, the propagation of the reverberations was destroyed by suspending a silk balloon in the centre of the ceiling.

In many other cases, the introduction of drapery, curtains, and other such materials, particularly carpets, sofas, and soft furniture in general, has a great power in absorbing sound. A speaker in the centre of any crowded hall or court, addressing himself more particularly to those who may have a position near the wall, is often not heard so distinctly as when he retires to the opposite wall, the power of reflection in some apartments adding more to the force of his voice than is lost by the distance.

713. In the Opera at London, sound is beautifully distinct from the elevated position of the singer on the stage, from the freedom with which the voice escapes, and from the absorbent surface upon which it falls in the boxes, pit, and gallery. There is only one spot upon the stage where a slight echo is perceived, which is produced by a distant surface near the ceiling. In apartments such as this, the unity and perfection of tone approximates to that which is observed in the open air, particularly on water or in a wood, where the absence of marked reflecting surfaces contribute so much to purity of sound.

714. In numerous cathedrals, both at home and abroad, distinct intonation, after the first two or three syllables are uttered, except within a limited distance, is impracticable, the

numerous echoes or reflections entirely confusing the primary sound, unless the sound of each note shall be so extended by slow chaunting, that it is strengthened by its own reverberation, instead of being interrupted by that of the succeeding note.

There are many public buildings in which the communication of sound is so imperfect, that it is no exaggeration to state, that the efforts of the speaker to be heard, and of those that listen to hear, detract very largely from the effective value of the discourse; while, in some parts of the building, the confusion is so great, that it is impossible with any effort to follow the subject of discourse, however loud the noise may be.

715. The stillness of an audience, and the exclusion of external noise, form very important elements in considering the communication of sound in public buildings. The character of the audience, also, particularly in rooms intended for music, requires to be taken into consideration. Loud noise is an essential element in some cases, though obtained at the expense of purity of sound and intonation, which ought ever to be considered the great object in attending to the communication of sound.

716. Where, however, the voice is feeble, and the apartment to be filled large and crowded, the reflection should be pushed as far as circumstances may permit, and the filling up or cutting off of superfluous space, which augments the power of intonation necessary, without benefit to the audience. In Glasgow, Edinburgh, and other places, churches and other buildings altered on this plan, have relieved much the efforts required for speaking and securing the attention of the audience.

717. Those who are interested in this subject will find, in general, that where the communication of sound is imperfect in the construction of public buildings, it may be remedied according to the acknowledged principles of acoustics, and particularly by providing an escape for excess of sound, in the manner introduced at the House of Commons, guarding it carefully from the influence of external noise. The additional impetus lately

given to the cultivation of music, under the sanction of the committee of the Privy Council on Education, in the interesting classes conducted by Mr Hullah, and the success that has attended his instructions, and those of Mr Mainzer, at Edinburgh, and other places, cannot fail to attract a more marked attention to a subject so intimately connected with the use of all public buildings; and an increased taste for music has always been followed by a more distinct perception of the difference between mere noise, which may be altogether unintelligible, and that purity of intonation which has been so often referred to. The public mind requires, in reality, to be much more alive to this point, and to the fact, that music is, of itself, and without any accompanying words, a universal language of the feelings, whose power is as determinate and marked as that of the most pointed language, in the expression of those emotions which it can portray; and that many are touched by its accents, whose heart and sympathies are not so amenable to the more common forms of address, whether from the pulpit or in the more retired communications of private life.

718. Much interesting illustration is also accessible to those who inhabit hilly countries, where the endless variety of forms, scenery, and outline, is continually presenting new features of observation, especially where different individuals arrange so as to communicate with each other under a great variety of circumstances. Some of the acoustic arrangements introduced at the House of Commons were founded on facts that were first presented to my notice during excursions with my pupils, who were studying the examination of soils, minerals, and mineral waters, with portable apparatus, such as enabled them to apply their knowledge practically on the open field, wherever they were directed to enter on any examination.

719. In the open air, in calm weather, and on plain ground, no difficulty was experienced in conversing without effort at the distance of 400 to 800 feet.

At night, the surface of the ground being free from the currents produced by the action of the sun (a circumstance which

Humboldt found to produce a great interruption to the communication of sound), and the hum of insects being stilled, the voice extended much farther, and satisfied us that the accounts given of its being heard at the distance of miles in the stillness of the polar regions could be no exaggeration. In the morning, before sunrise, the voice, and occasionally the laugh, of the sailors on board the war-ships at anchor off Spithead, have been heard at a place at Portsmouth, distant two and a half miles in a direct line. The sound of a military band at the hour of roll-call has been heard at the distance of twenty-one miles from Edinburgh Castle. In one of the illustrations I laid before a committee of the House of Commons, I explained the circumstances under which Admiral Stoddart and his officers heard (at sea, in the Baltic), as they proved afterwards by a very interesting chain of evidence, the sound of cannon, for a whole day, at the distance of 300 miles.* Colonel Dod, with several hundred troops, was on one occasion under arms all night, it being considered on shore that there was an engagement at sea; but the noise heard was afterwards found to have proceeded from a volcano at the distance of 400 miles. It has been stated that there are despatches in the Government offices detailing supposed engagements heard by ships at sea, and that the sound came in reality from a volcano at a distance of 900 miles from the position where the sound was heard.

720. But there are few localities where numerous facts might not be accumulated, such as have been adverted to in regard to the communication of sound, illustrative equally of the power of the voice and of the air in a still atmosphere. And the general conclusion appears to be, that few buildings have yet been constructed too large for the human voice to fill, where excessive reverberation can be subdued, where the audience maintains a careful silence (for the breathing of multitudes sometimes pro-

* The cannon were fired at a foundry where the men were proving cannon all day, and when the fleet met at a future period, it was found that it had extended over a line of 300 miles. All the ships heard the cannon sounding, and some sailed opposite the foundry at the time they were fired.

duces offensive noise), and where the unity of the atmosphere is preserved.

721. In many apartments, the distinctness of intonation is impaired by the different strata of hot and cold air at different levels, which refract the sound unequally as well as the light.

722. The following tables explain the manner in which the state of the ventilation is registered at the House of Commons, and the more extended tables, which have been begun, but which are not yet in such full operation as is desirable, as all the instruments which are in use have not yet been reduced to that simplicity which it is expected to attain. The great object of these registers is to enable the attendants to acquire experience in the various contingencies which they have to meet, and particularly, to enable them to anticipate, as far as possible, every expected change of atmosphere.

723. The state of the air, externally and internally, is examined, from time to time; and before I resided in this city, specimens were transmitted every week to Edinburgh, through the office of Woods, which enabled me to maintain a constant check on the state of the ventilation.

724. In the first experiments made on sound and ventilation at the House of Commons, after the completion of the alterations, the benches were occupied by 400 of the Guards, in their winter dress and great coats. About 150 gentlemen then placed themselves in different parts of the House, and after a series of trials were made on the communication of sound,* large trains of gunpowder, previously mixed with oils and perfumes, to increase the fumes and prevent detonation, were fired in the chambers below. The House was filled, at once, with so dense a smoke that few could see each other, but in a few minutes it was clear, the full power of the ventilation having been put on. Successive varieties of atmosphere were then introduced, in which the air was

* Had the experiments on sound been made on empty benches alone, the results would not have been satisfactory, from the causes previously explained.

affected by a variety of chemicals communicated to it in the chambers below.

725. The amount of air given at the Houses is least when there is no demand for moisture in the air, and when the constitution has been exhausted by long exertion without refreshment.

726. The highest supply is required in autumn, when the air is warm and moist, the wind imperceptible, but inclining from the east, the barometer low, and the ground moist, and the tide full. Fifty thousand cubic feet per minute are scarcely sufficient then to sustain comfort in a crowded House; extra power is given, and the other appliances resorted to which have been stated.

(The valve referred to in the opposite tables is ten feet long and six feet deep. It indicates that the area through which the air passes is sixty feet; when it is opened six feet. On multiplying the extent to which it is opened by ten, the precise opening at any recorded period is given.)

Extracts from Tables as they have been kept at the House of Commons from the year 1837 to the present time.

May 22d.—Session 1837.

State of the Atmosphere.	Hour.	Temperature External Air.	Temperature in Air-Chamber.	Temperature East Gallery.	Temperature at Chair.	Temperature West Gallery.	Temperature in descending shaft.	Valve opened. Ft.	Valve opened. In.	Members and Strangers present.
Very dull. . .	4 P. M.	55	63	60½	62½	61½	60	1	3	120
...	5	54	64	63½	63½	63½	61	1	3	280
...	6	52¾	64	64½	64½	64	62½	1	0	330
...	7	51	69	64	64½	63½	62½	1	0	200
Clear star-light.	8	50	69	65	65	65	64	1	6	270
...	9	48	64	65½	65½	66	65	2	0	348
...	10	45	56½	65½	65½	66	65	2	6	678
...	11	44	54¾	66	66	66	66	2	9	720
...	12	43	52	66	66	66	66	2	9	760
...	1 A.M.	42	50	66	66	66	65	2	9	760
...	2	41	50	66	66	66	65	1	9	800
...	3	40¾	65	65½	66	65½	64	1	0	40

May 12th.—Session 1843.

State of the Atmosphere.	Hour.	Temperature External Air.	Temperature in Air-Chamber.	Temperature East Gallery.	Temperature at Chair.	Temperature West Gallery.	Temperature in descending shaft.	Valve opened. Ft.	Valve opened. In.	Members and Strangers present.
Clear and fine,	4 P.M.	61	60	64	63	62	65	1	0	130
...	5	60	59	66	65	65	67	3	0	350
Rather dull, .	6	59	58	67	66	66	68	3	0	431
Rain, ...	7	57	57	67	65	66	69	2	6	160
...	8	56	57	67	65	66	72	2	6	170
...	9	55	57	68	65	66	72	2	6	200
Showery during	10	53	27	68	65	67	72	3	6	320
the rest of the	11	53	58	68	66	68	72	4	6	520
sitting.	12	53	59	69	67	69	73	5	0	600
...	1 A.M	53	60	71	68	70	73	5	0	640
...	2	53	60	72	68	70	73	5	0	600
...	3	53	60	71	67	69	73	5	0	450
...	4	53	60	69	66	68	71	3	6	240

..sion. TEMPORARY HOUSES OF PARLIAMENT. *Session* 1843.

Hour.	External Atmosphere.							House of Lords.								House of Commons.											Materials Used			
								Air entering the House.			Thermometers in House.					Air entering the House.				Thermometers in the House.										
	General Remarks.	Thermometer.	Hygrometer.	Carbonometer.	Barometer.	Anemometer.	Electrometer.	Natural.	Hot.	Cold.	Throne.	Table.	Bar.	Valve opened, Ft. In.	Members and Strangers Present.	Natural.	Hot.	Cold.	Thermometer in Lower Chamber.	East Gallery.	Chair.	West Gallery.	Thermometer in Ventilation above Ceiling.	Thermometer in descending Shaft.	Valve opened, Ft. In.	Members and Strangers Present.	Ice Water, or Steam.	Fuel consumed in Boilers.	Fuel consumed in Shaft.	Velocity of Current.

PART V.

MISCELLANEOUS ILLUSTRATIONS OF VENTILATION.

727. THE following illustrations explain different points connected with the general disposition of ventilating arrangements, which could not be introduced into the preceding parts without interfering too much with the more immediate object of the questions under examination. It will be seen that ventilating arrangements are necessarily as varied in their details as the peculiar circumstances under which they have to be applied.

728. In the construction of new buildings, the illustrations given in Figs. 241, 242, shew the general disposition of the primary air-flues which it is important to introduce. Fig. 241 shews those *in the basement*, designed for the reception of fresh air at the four points *a a a a*, the great channels *b b b b* being, at the same time, reservoirs for the distribution of tempered air to all the various apartments proceeding from them. Fig. 242 indicates the disposition of the parallel vitiated air-flues *m m m m* in the roof, receiving the vitiated air from all the apartments supplied by the basement, and conveying it to the central shaft *x*, by which it is finally discharged.

729. In such buildings, besides the supply afforded by the arrangements shewn in the preceding figures, it is important, in

Fig. 241.

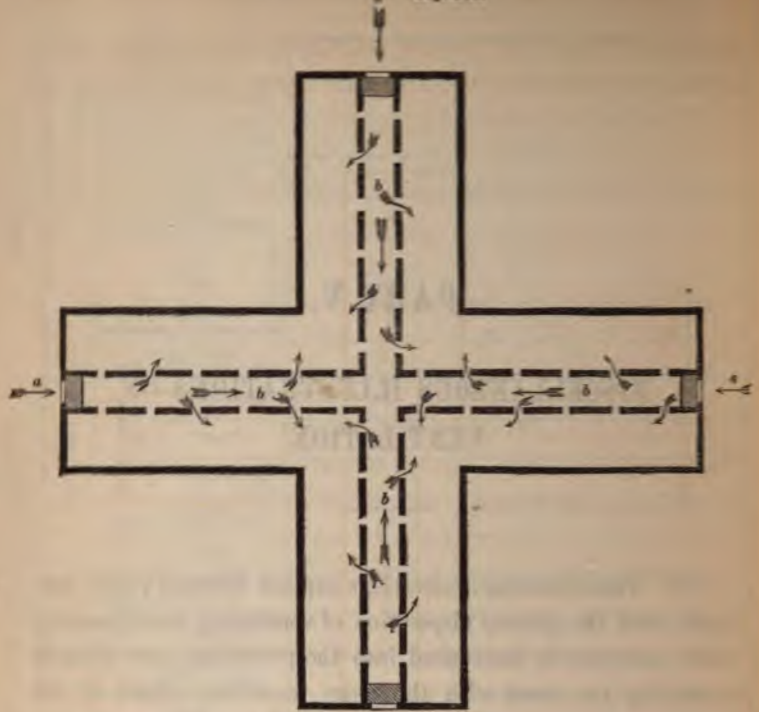
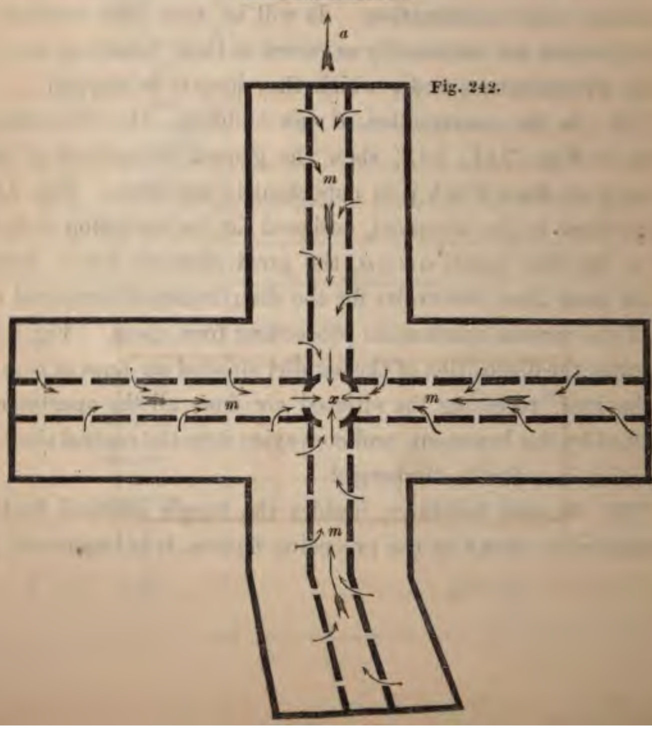
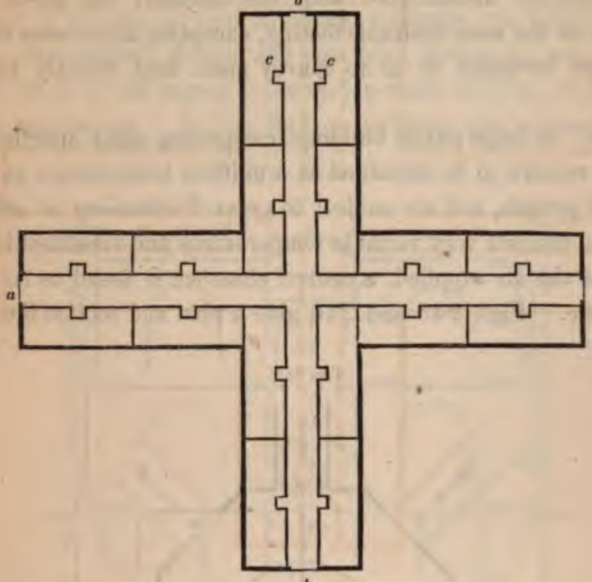


Fig. 242.



many cases, to have the power of flooding the corridors with fresh air from $a\,a$, and from $b\,b$, Fig. 243, by opening windows, so

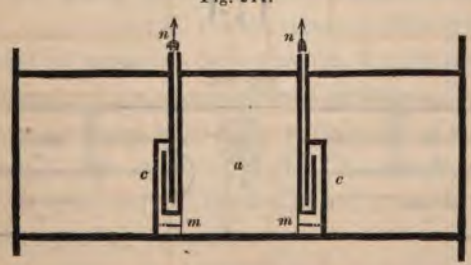
Fig. 243.



that in whatever direction the wind may blow, its power is easily brought to bear upon them.

730. The recesses in the corridor marked $c\ c$, in the preceding figure, refer to an enlarged section given in the following figure (244), where a represents the corridor, m the fire-place

Fig. 244.



of an exclusive stove, c a section of the stove, and of the apart-

ment which it heats, and n the chimney. This stove being attended and managed entirely from the corridor, it is obvious that, if the apartments be supplied with air and ventilated by arrangements unconnected with the corridor, the stoves are placed on the most desirable footing, excepting those cases where they are arranged so as to convey more heat directly to the floor.

731. In large public buildings comprising many apartments, which require to be sustained at a uniform temperature at particular periods, and are subject to great fluctuations at others, so as to demand very variable temperatures and velocities in the state of the air supplied, a central chamber is found to be very desirable. Figs. 245 and 246 give a plan and section illustra-

Fig. 245.

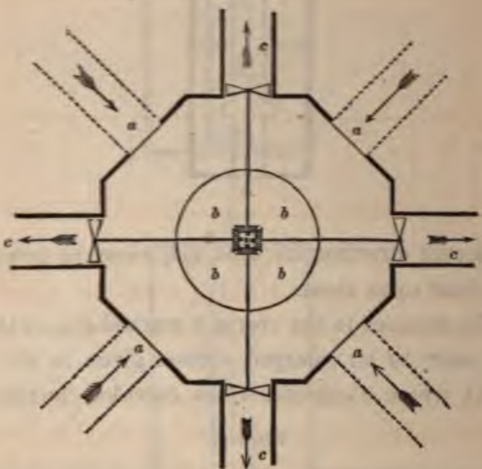
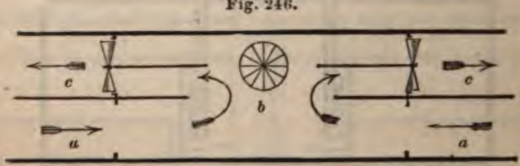


Fig. 246.

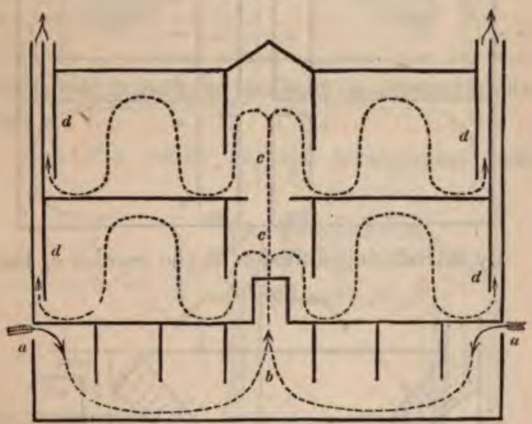


tive of such chambers, *a* indicating the channels for the ingress

of air, *b* machinery for its propulsion, and *c* the channels for conveying it where it is required.

732. In mansions constructed with the usual accompaniments of a large establishment, it is very common to observe a large amount of vitiated air from kitchens, sculleries, gas-lights below stairs, beer-cellars, drains, and dust-bins, finding its way to the principal hall, and from it to the dining-room, drawing-room, and other apartments. In Fig. 247, *a* indicates the ingress of air

Fig. 247.



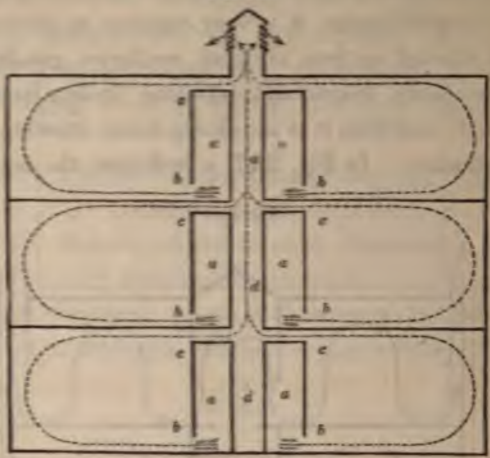
to supply the kitchen and sculleries, *b* its progress to the principal staircase, *c* the course it takes from the staircase to the individual apartments, and *d* the chimney-flues by which it escapes.

733. Fig. 248 illustrates the principles that ought to be adopted in preventing the movements described in the preceding paragraph. *a* points out all the staircases so largely flooded with warm air that no room can draw through it upon the air of another apartment; *b* the supply of fresh air from *a*; *c* the escape of vitiated air from the individual apartments; *d* a discharging shaft, so ample and so powerful that it controls directly the vitiated air in every part of the house, and prevents any portion from one place passing to another.

734. In arranging the ventilation of any ordinary apartment,

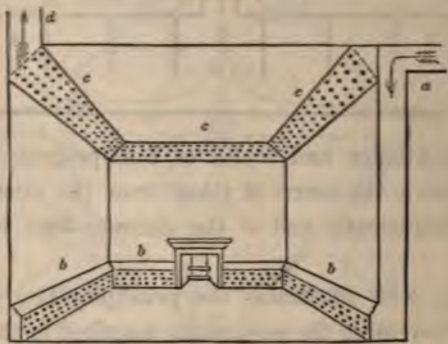
air introduced by *a*, Fig. 249, should be diffused at the skirting board *b*, and discharged by a channel *d* proceeding from the

Fig. 248.



ceiling. By introducing diffusion at the cornice *c*, the ventila-

Fig. 249.



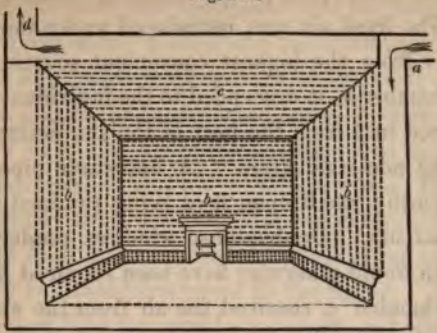
tion is improved. When gas-lights are used, or oil-lamps, they should be arranged as described in the chapter on lighting.

735. Before the ventilation of any apartment can be at all depended on, it must be seen that the source of supply, and the channel of discharge, are not subject to the counteracting influence of any local current, or unsupplied fire-place, drawing on a passage.

736. When the most extreme diffusion is required in small

apartments, in consequence of sickness, the internal fittings may

Fig. 250.



be arranged with porous materials in the manner represented in Fig. 250.

737. Fig. 251 points out the arrangements adopted for

Fig. 251.

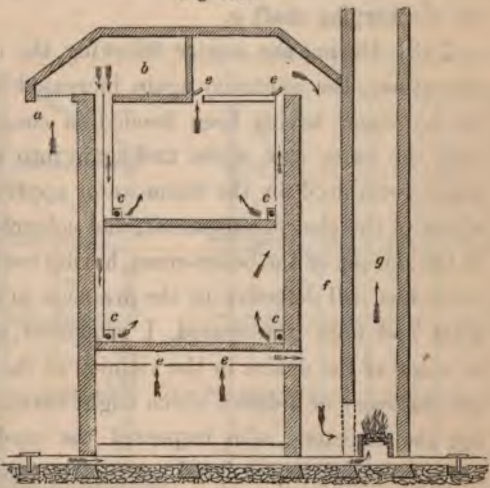
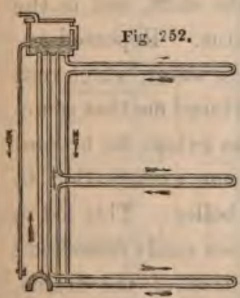


Fig. 252.



ventilation in an hospital where the circumstances were altogether peculiar, and where the mortality had been excessive. The hospital had been built for about 15 years. Every thing looked substantial, fresh, and clean; but the atmosphere in the vicinity, and the currents of cold air within the hospital, formed peculiar subjects of complaint. An examination of the air in the basement having assured me that it was of very inferior

quality, and many circumstances having combined to prevent the expediency of other plans, the following scheme was finally adopted:—The fresh air was introduced under the roof *a*, that it might enter from the highest convenient source. From the general air-chamber *b*, it descended to the individual apartments, being protected in *b* from the heat of the sun acting on the roof by intervening non-conductors. A hot-water pipe *c*, gave it a moderate warmth; small open fires being retained for the comfort of the patients. Double-glass windows rendered less heat necessary than would otherwise have been required in winter. A vitiated air-chamber *e*, received the air from the wards, its discharge being regulated by valves. The air in the basement was prevented from passing into the wards above by the flue *e*, the air from it, with that from the chamber *e*, in the roof, passing to the descending shaft *f*, from which it passed ultimately into the discharging shaft *g*.

738. During the winter following the introduction of these alterations, the mortality again increased in the hospitals, and the basement having been flooded in consequence of excessive rain, the water rose again and again into the shaft, and in the boiler-room used for the warm-water apparatus. Repeated analyses of the clear, transparent, and colourless water, which rose in the ash-pit of the boiler-room, having convinced me that something was still defective in the drainage to an extent far beyond what had been anticipated, I requested some examination to be made of the drains in the vicinity of the boiler. This led to the discovery of a defect which might have been easily remedied; but the directors, who inspected the condition of the drains, having immediately ordered a complete examination beyond the immediate question that engaged attention, it was finally ascertained that the main drain was entirely and absolutely blocked up with two wooden rollers,—that the whole basement was flooded with every description of decomposing impurities, and that it was impossible to tell precisely how long this state of atters had continued. The whole ground must have been sated with impurities to an extreme extent.

739. From the special difficulties that were presented in the adjustment of the hot-water apparatus, and the strong objections I made to the use of any part of the basement as a source or reservoir of hot air, before the discovery of the state of the drains was made, it had to be constructed so as to suit the circumstances of the case, and not in the manner most desirable under other circumstances. The hot-water reservoir, shewn in Fig. 252, was supplied from a horse-shoe boiler, and the individual floors received each a special branch, which, after traversing the apartments to be heated, returned to the boiler. The fire from the boiler worked into the ventilating shaft, and the air from the drain was consumed by the fire in the shaft, as is represented in Fig. 252.

740. Figs. 253, 254, and 255, point out the system adopt-

Fig. 253.

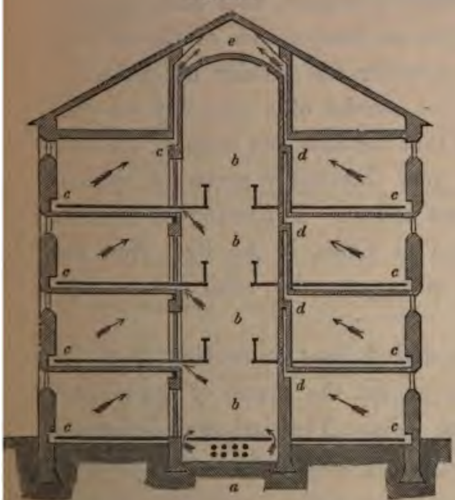


Fig. 255.

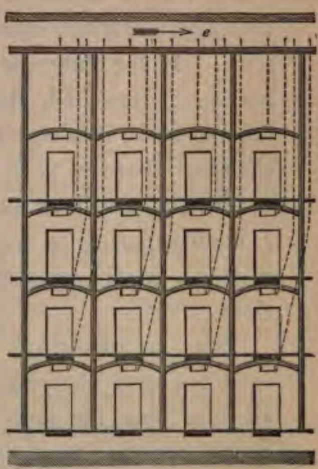


Fig. 254.

ed in some of the prisons which I have ventilated, and the arrangements made in such cases as were not altered, with the view of meeting peculiar circumstances. The air having been

obtained from a source where it was subject to no contamination, was conveyed to a central channel—that containing the 8 pipes represented above *a*,—and being warmed as might be necessary by the extent to which the pipes were heated, gained access to the great corridor *b b b*, as represented by the arrows. The three upper cells receive fresh air, as shewn to the left in Fig. 253, and the lower cell is supplied as indicated in Fig. 254. The air traverses all the cells so as to warm the floor, and escapes into the cell at *c*; the vitiated air is discharged at *d*, as shewn in the cells on the right,—the vitiated air from all of them being collected ultimately in *e*. From *e* it escapes into the external atmosphere by a shaft ascending directly or descending, as other arrangements may determine. An ascending movement is always preferred, where it can be secured with sufficient power.

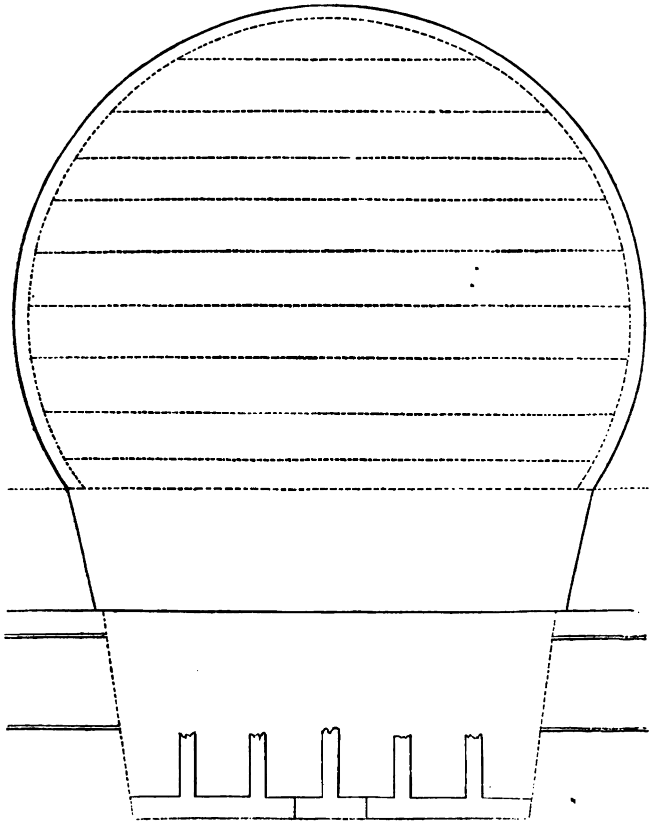
741. It is scarcely necessary to remark, that such arrangements give extreme equality in the temperature of the air supplied. If the materials at *a*, under the tubular hot-water apparatus represented, shall not consist of a very dry non-conducting basis, it is essential that the floor and sides of the hot-chamber above *a* shall be very thoroughly protected by non-conductors, that heat may not be lost. In forming the chamber *e*, double glazing is required at times, if the light from the windows, at the extremity of the corridor, shall not be sufficient.

742. In Fig. 255, the dotted lines proceeding from the openings below the vaults point out the course of the vitiated air-flues from the individual cells. The dark area below the door shews the site of the ingress of fresh air for the superincumbent cell.

743. The ventilation of theatres has received a considerable impulse of late; but it can scarcely be expected that buildings of such magnitude can always be easily ventilated, more especially when the public appetite for air is still on so low a par, and when there are so few standards of comparison to appeal to. Let any one, for instance, look to such a building as the Opera

(the pit is represented in Fig. 256, with some ventilating arrangements for the stage), and, after counting the number of

Fig. 256.



persons present, and allowing twenty respirations for each per minute, let him see from what source the supply of air is to be derived. Farther, let him consider that an excess of air is required in summer, in consequence of the proximity of those who occupy the benches, and the warmth they communicate to each other and to the place, and he will soon see the great amount of supply that is necessary. The present lessee of the Opera in London has done a very great deal for its ventilation, so that much more vitiated air can be withdrawn from it than formerly,

and several other improvements have been made, particularly at Her Majesty's box. It is impossible, however, to provide this house, or theatres generally, with that amount of ventilation which is now considered desirable, unless proper means be taken for the ingress of large supplies of fresh air, as well as for the discharge of that which has been vitiated.

744. In considering the question of theatres, it may be remarked, that the nature of the air supplied is so very various in different cities in Europe, at different periods of the year, that each ought to have its own standard in this respect, according to the intensity of the changes which it may be necessary to meet. The following figures will serve as a general guide to the most important points desirable in all theatres of the usual construction:—

1. A legitimate source or sources for the ingress of air, *a a*, Fig. 257, should be provided. The supply, under other circumstances, will always be defective, particularly when the curtain is down.

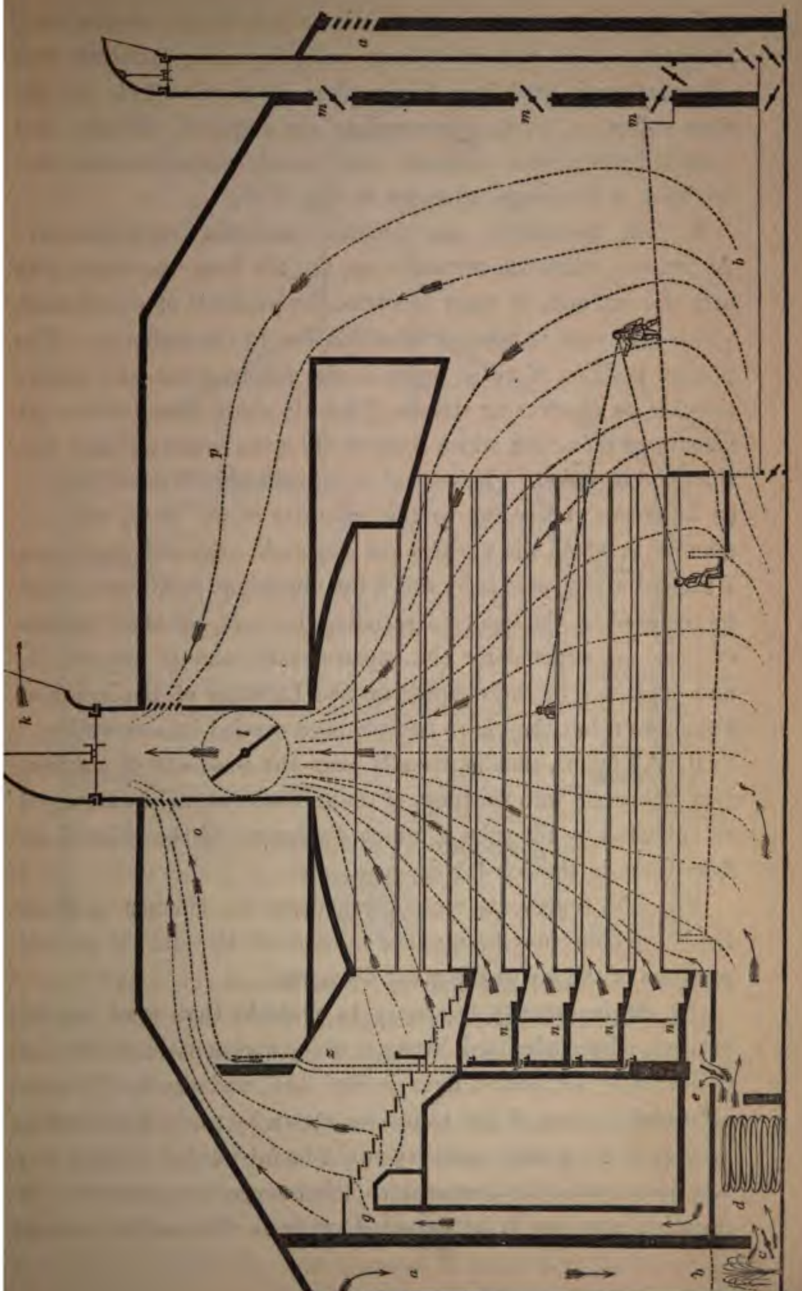
2. In sultry weather, a fountain *b*, or other arrangements, to cool the air, is extremely useful.

3. A controlling valve *c*, to regulate the force of the entering current, according to the state of the wind, is indispensable.

4. A heating apparatus *d* is required in cold weather, unless the atmosphere is to be heated by the audience, or by the return of vitiated air from gas lamps, the products of which may not be permitted to escape from the roof.

5. A channel *e* supplying fresh air to the galleries, and through *g* to the box-lobbies through *n* (for the boxes), so that neither galleries nor boxes are supplied with vitiated air that has been respired below.

6. An external discharge, of ample dimensions, protected by a cowl *b*, or other means, capable of being regulated by a valve *l*, and discharging air from the galleries, the stage, and the lofts above, the roof being constructed so as not to cool and precipitate the vitiated air upon the audience.



7. An independent discharge, connected with the stage above, and used to bear with great force on deflagrating mixtures and other materials used from time to time for scenic effect, the various valves *m*, *m*, *m*, commanding any required altitude, and communicating with channels and branch channels occupying the back of the stage, as shewn in Fig. 257.

8. The foot-lights also demand particular consideration. At present, when the curtain is up, the air from the stage rolls over the pit, and, in many theatres, the products of combustion which they emit is inhaled, after dilution, by the audience. The present position of these lights is also inconvenient and objectionable, as the waving stream of hot air above them induces an amount of refraction which impairs alike the sound and the distinctness of vision. This is not so objectionable in some theatres as in others, according to the intensity of the light, and the manner in which the burners are disposed. Several years ago, I shewed arrangements by which the objections mentioned might be removed by the use of descending burners, on the principle of those constructed for the experimental room at Edinburgh, and explained in the chapter on the Lighting of the House of Commons; but they have not yet been carried into execution.

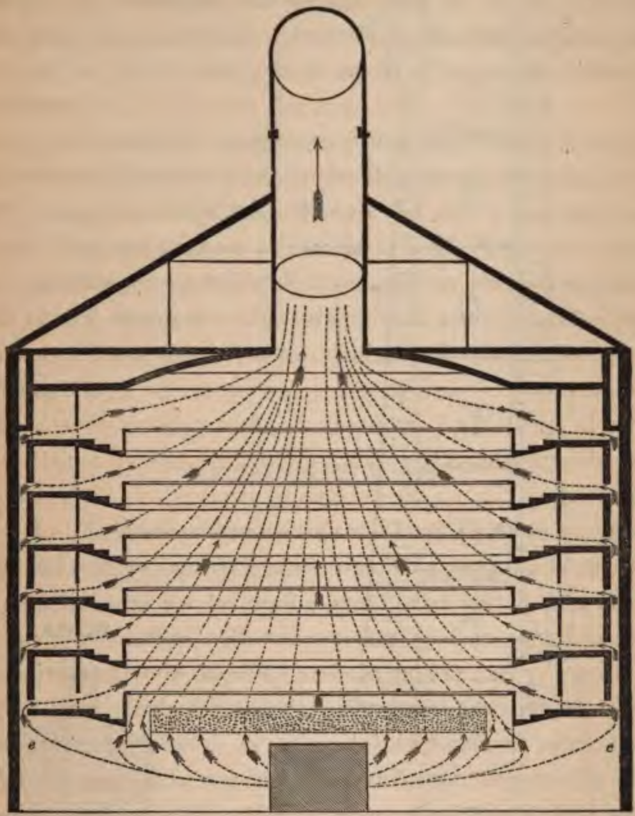
9. All lamps, such as usually pour the products of combustion ultimately into the lungs of the audience, should be arranged as indicated by the tube *z*, which discharges all the vitiated air from those in the box-lobbies *n*, *n*, *n*, *n*.

Fig. 258 represents more particularly the manner in which the box-lobbies may be supplied with fresh air, and the general progress of the air to the great discharge.

10. It is scarcely necessary to remark, that were minute portions of air admitted between every two seats in the pit, as indicated by the dotted lines in Fig. 256, and also by the sides all round in front of the boxes (as shewn by the porous surface in Fig. 258), a large quantity might be introduced without any sensible impulse, its temperature being properly regulated. In no other way can it be expected, without diffusion, to control

draughts at doors, and to repel the influx of so strong a current from the stage.

Fig. 258.



11. The atmosphere from the apartments below and adjoining the stage, should also be drained and carried off through an independent channel, instead of rushing in on all sides, as at present, to the body of the theatre.

745. Fig. 259 gives a section of the Skerryvore Lighthouse, erected by Mr Alan Stevenson, in which, it may be observed, the smoke flues from *a* and *b* are carried to a great altitude, in order that an effective discharge of the products of combustion may be insured. The dome *f* is made double, so as to

Fig. 259.

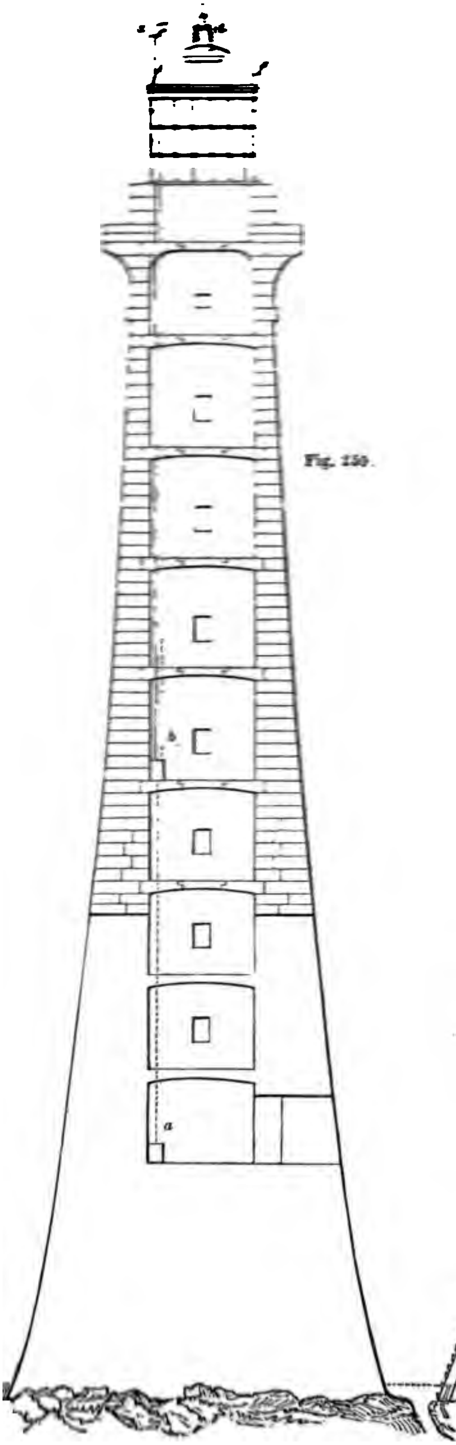
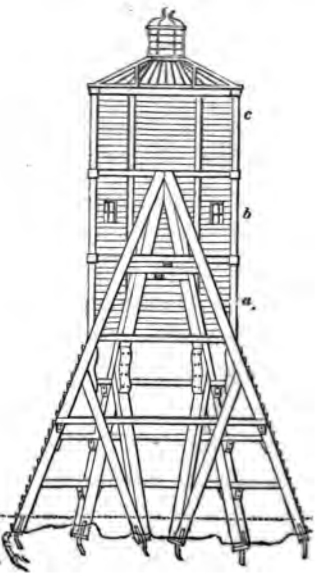


Fig. 260.



prevent the action of cold in condensing any moisture within. Any drops of water returning from the colder louvres on the top, are usually received in a small pan in the manner represented. Mr Stevenson informs me, that no cases of condensation upon the glass have occurred in the Scotch lighthouses arranged in this manner, such as Mr Faraday has observed elsewhere.

Fig. 260 shews the temporary beacon in which the engineer and workmen lived occasionally for four months at a time, while constructing this important work. On one occasion, during winter, when the works were interrupted, the beacon was washed away, and the sea passed over it entirely, as was ascertained on their return, from marks left on the light-house. *a* Cookhouse and store; *b* engineer's cabin; *c* workmen's barrack, where 30 men slept.

VENTILATION OF COACHES.

746. The intolerable condition of the atmosphere in coaches, when the windows are long shut, and the seats all occupied, is too familiarly known to require any explanation. The following are the principal observations that have occurred to me in connection with the ventilation of coaches.

747. The want of an accredited ingress for fresh air, and of a discharge for vitiated air, were, till very recently, almost universal defects. The windows are sufficient only in fine warm weather, and even then the traveller who has not the advantage of a seat with his back to the horses or the engine (when constitutional peculiarities do not render that seat inconvenient by inducing headache or nausea), frequently suffers severely from offensive currents playing upon his mouth and nostrils, particularly if the window shall be opened when he is asleep. Few in this position are not apt to suffer from cold, unless the constitution shall be powerful. I have seen nothing give so much relief to those who require air, and are necessarily exposed in this manner, as throwing a shawl or plaid loosely over the

head and shoulders, and adjusting the folds so that no air can blow directly on the mouth and nostrils, while stagnation is entirely prevented.

748. In very cold weather, the moisture of the breath is so rapidly condensed by the ice-cold glass, that the greatest source of oppression is quickly removed, and cold still proves a greater evil than a vitiated atmosphere. The windows are therefore, in general, kept very close. Such a condition, however, though, on the whole, the most generally agreeable, is often very distressing to many constitutions, particularly where the floor of the coach is only imperfectly protected. I have repeatedly noticed, in such cases, in extreme weather, a difference of from 12 to 16 degrees between the temperature of the air around the head, and that at the feet.

749. Some railway coaches are now so excessively ventilated above the level of the head, that they feel most uncomfortably cold to those who take their places in them in severe weather.

750. On the whole, then, it may be concluded, that coachmakers would do well to attend to the following circumstances:—

1. To provide openings for the ingress and egress of air, independent of windows, so that they can be controlled in severe weather.
2. To admit the air in such a manner, that, in cold weather, it may receive some warmth from the upper part of the coach before it reaches the floor.
3. To admit the air with extreme diffusion.
4. To discharge the vitiated air from the upper part of the coach, giving the power of regulating the amount of discharge by a valve, under the control of those within.

751. Such arrangements would meet the principal desiderata, and enable many a weary traveller to escape much of the oppression, colds, rheumatism, or other ailments, that frequent-

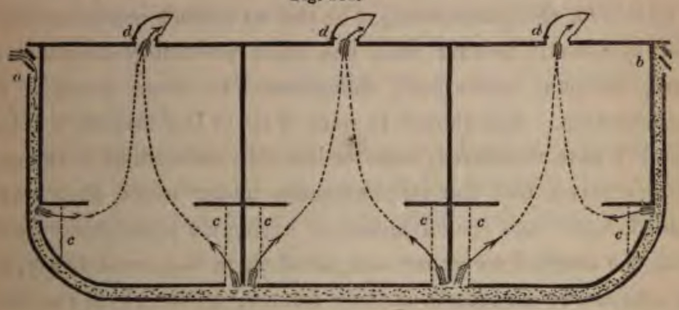
ly attend him on a long journey, besides permitting many to sleep whose habits enable them to take repose at night in coaches, when not disturbed by a vitiated atmosphere that induces headache.

752. It would also require very little ingenuity to construct the floor of iron, so that, in severe weather, it might be made to offer a gentle warmth, sufficient to take away all sensation of cold. Small loaves of prepared charcoal, requiring merely to be kindled at one end, or a small lamp, might be used, whose combustion is sustained, by air entering and discharged altogether without the coach, and having no communication whatsoever with the interior. The supply of air would regulate the amount of combustion.

753. In common coaches, the heat of the lamps used at night might be made, with a very little contrivance, to provide a warm resting-place for the feet of the outside passengers.

754. In the accompanying figure (Fig. 261), representing

Fig. 261.



a railway coach, *a* and *b* represent openings admitting a supply of air from either end of the coach; *c* the surface of diffusion, the amount of air permeating through it being entirely under control; *d* discharging cowls in the roof, which could be made to any pattern. By regulating the amount of opening left in them according to the state of the weather, the velocity of the train, and the action of the wind, the ventilation could, in most cases, be very easily adapted so as to give greatly increased comfort to travellers both in summer and winter.

PART VI.

VENTILATION OF SHIPS.

---

755. Few fields present more interesting or important opportunities for improved ventilation than those that are offered by the different classes of ships in the navy and in the merchant service; and entertaining the conviction that the means that are available for this purpose might be put on a much more extended and systematic footing than had been previously adopted, I have, for many years past, endeavoured to direct attention to this question. And though in none of six of Her Majesty's ships which I have ventilated, more or less fully, according to the authority given, and the circumstances under which they were placed, have I had the advantage of having my plans intertwined with the original structure, and all of them had, accordingly, to be adapted to structures already formed, or for which the preparations of the materials were so advanced that no time was given for the modifications that would otherwise have been made in them, the arrangements introduced are still sufficiently explanatory of the system recommended, and of the mode in which it operates. It may be proper for me here to acknowledge the opportunities of communicating with the committee of master ship-wrights, which Sir George Cockburn afforded me, when they were assembled at Woolwich, about two years ago, and the assistance which I then received from Mr Creuze of the Portsmouth

Dockyard, who continued for several months in my office, according to the instructions of the Lords of the Admiralty, when I was engaged in preparing the report submitted to the committee of master ship-wrights. I have likewise to express my acknowledgments to Mr Creuze, as I have stated formerly in my pamphlet on the Niger Expedition, and to Mr Chatfield of the Plymouth Dockyard, with whom I was more especially placed in communication in carrying out my plan for the ventilation of the Minden, a seventy-two gun ship, now used as an hospital ship for troops and sailors in China.

756. At a former period, I have also to state, that Captain Houston Stewart (of the Benbow) gave me a very important opportunity of studying the state of the air on board a ship-of-war at sea. Commander Hathorn, Mr Allan the surgeon, and the other officers, also assisted me in the experiments and observations I made. Three instruments were employed in these experiments, one of which was an iron-fanner, which I had used previously in illustrations of ventilation, given at Edinburgh in 1831, and subsequently at the Gulan Experimental Light-House, near Edinburgh, in a series of experiments made there, along with Mr Alan Stevenson, the engineer to the Commissioners of Northern Lights.

757. In perusing the following pages, the reader is requested to bear in mind the view expressed in the first part of this work, in referring to the influence of ventilation on different conditions of life.

I take this opportunity of stating, in reply to various communications that have appeared during the last twelve months, and which have been very generally circulated, that they are as incorrect as any statements can well be. It has been, for instance, most industriously affirmed, that, in a vessel recently constructed, I took several feet from the sides of the principal cabins, that I might accommodate the ventilating tubes introduced. It is difficult for me to understand how any statement so utterly at variance with the fact could be so frequently reiterated as that was, under

all the varied circumstances in which it was presented to me, by any one who had not deliberate misrepresentation in view; but the extent to which this and other statements equally groundless have been made, call upon me to repudiate them in the strongest language I may be permitted to employ, and to mention, that I have three times requested investigation on this and some other points,—otherwise the mere hardihood with which they have been made might lead many to entertain the opinion that they were true,—as the only defence which is open to me under the circumstances to which I have adverted. The tubes referred to were introduced in the vacant spaces I found after the bulkheads had been made and arranged in the places which they now occupy.

CHAPTER I.

PECULIARITIES OF SHIPS—THE SLEEPING BERTH OF THE SAILOR.

758. The state of the air in ships is much influenced by their construction—the materials of which they are formed—the purposes to which they are applied—the presence or absence of the steam-engine—the climates which they visit—the cargoes which they carry—the number of persons that may be crowded within a given space—the diet that may be provided—and the discipline and usages which may be enforced.

759. The ventilation of ships has not hitherto been placed on that extended and systematic footing which is necessary to insure comfort and success; but it has been much improved in late years, at least in the navy. The sailor's health has been benefitted not only by this circumstance, but perhaps still more essentially by the larger allowance of the necessaries of life which he now receives. Many of those injurious effects which have been sometimes attributed to a want of ventilation, have not in reality arisen from this cause alone, but have been dependent on other circumstances associated with this evil. Of these, none have produced so marked an effect as insufficient nutrition, conjoined with defective ventilation. Defective ventilation impairs the appetite, and thereby reduces the tone and strength of the constitution. Inefficient nutrition, on the other hand, renders a smaller supply of air endurable than would otherwise be tolerated. Thus, then, these two causes lead to the most injurious results, in modes that require much consideration, as, if a desirable proportion of air be given, the amount of food being deficient from an unfortunate or incorrect standard having been taken, the

sailor may have enough of ventilation but too little food. But if the amount of air supplied be too small, the deficiency may reduce the power of using advantageously the necessary supply of food where it is freely accorded. It is impossible to study the state of the health of the navy in former times, without being satisfied that defective ventilation was perhaps the true cause of the erroneous standards formerly adopted in regulating the quantity of food; and in considering the numerous evils that have been avoided latterly, by a number of measures, it is difficult, or rather altogether impracticable, to say how much benefit ought to be attributed to the larger amount of food, its superior quality, better ventilation, the reduction of the daily allowance of spirit, and other changes bearing on the moral and social condition of the sailor. The valuable Statistical Report on the Health of the Navy, by Dr Wilson, amply illustrates the importance of these questions. The opinion I have given as to the probable source of the inefficient supply of food formerly allowed in the navy, appears to me strengthened by all the facts on this point I have been able to ascertain, proving that it was impossible for the appetite to be good in an atmosphere so loaded with impurities as it usually was on board ship.

760. The peculiarities which require the first notice in looking to any systematic measures for the ventilation of ships, are the following:—

761. I. All ships contain cavities under the surface of the water, the whole of which, on some occasions, in severe storms, it is necessary to render air-tight, or nearly so (excepting, perhaps, in the largest war ships, which are not so subject, from their great altitude, to ship a sea, and where, accordingly, the hatches on deck are rarely closed); it is impossible, therefore, to ventilate them effectually in those cases where the necessity for ventilation is greatest, unless some power be applied, either by heat or by mechanical means, to force a change of air through such small openings as the safety of the vessel may permit.

762. II. The extreme value of various spaces in ships of ar, which might otherwise be most advantageously applied for

the purposes of ventilation, renders it necessary to adopt some channels that would not otherwise perhaps be chosen.

763. III. Ships at sea, and even ships at anchor in any tidal stream, are not only subject to the variations of the external atmosphere, but the various movements or altered positions induced in them by a change in the tide, in the wind, or in the tack upon which they may sail, often produce extreme changes in the atmosphere to which the individual sailor is exposed. For instance, the air in the lower deck of ships is in general found to move gently by a variety of currents, if all the ladder-ways and hatches be open, entering at some and escaping at others, when the men are asleep. But should the position be altered by the tide or any other cause, the wind continuing as before, then those individuals whose bodies may have been bathed in perspiration, from the warmth of the heated air from their neighbours passing over them, perhaps for hours previously, may now be suddenly subjected to a cold stream of air, from a change in the direction of the currents, while those that were formerly in this position may be as suddenly subjected to the warm current of vitiated air.

764. IV. Sailors generally sleep under circumstances altogether in opposition to the natural laws of ventilation and respiration. The body is so formed that the vitiated air from its surface, and from the lungs, tends to escape by an ascending movement (see Respiration). But the position of the hammock of the sailor, as illustrated in the accompanying Figs. 262, 263, 264, 265, taken from the lower deck of a first-rate line-of-battle ship, shews that the sailor, when asleep, must generally be enveloped in a vitiated atmosphere. His sleep is not of that refreshing character which is desirable. In warm weather his face is frequently flushed, and suffused with perspiration; and even in frosty weather, when the decks are crowded, the same thing may often be observed, though to a less extent.

765. Fig. 262 illustrates the general disposition of the hammocks in the lower deck of a man-of-war, where the sailors sleep, and when they are not berthed with that extreme closeness which is too often resorted to, if there be a very full complement of men.

Fig. 202.

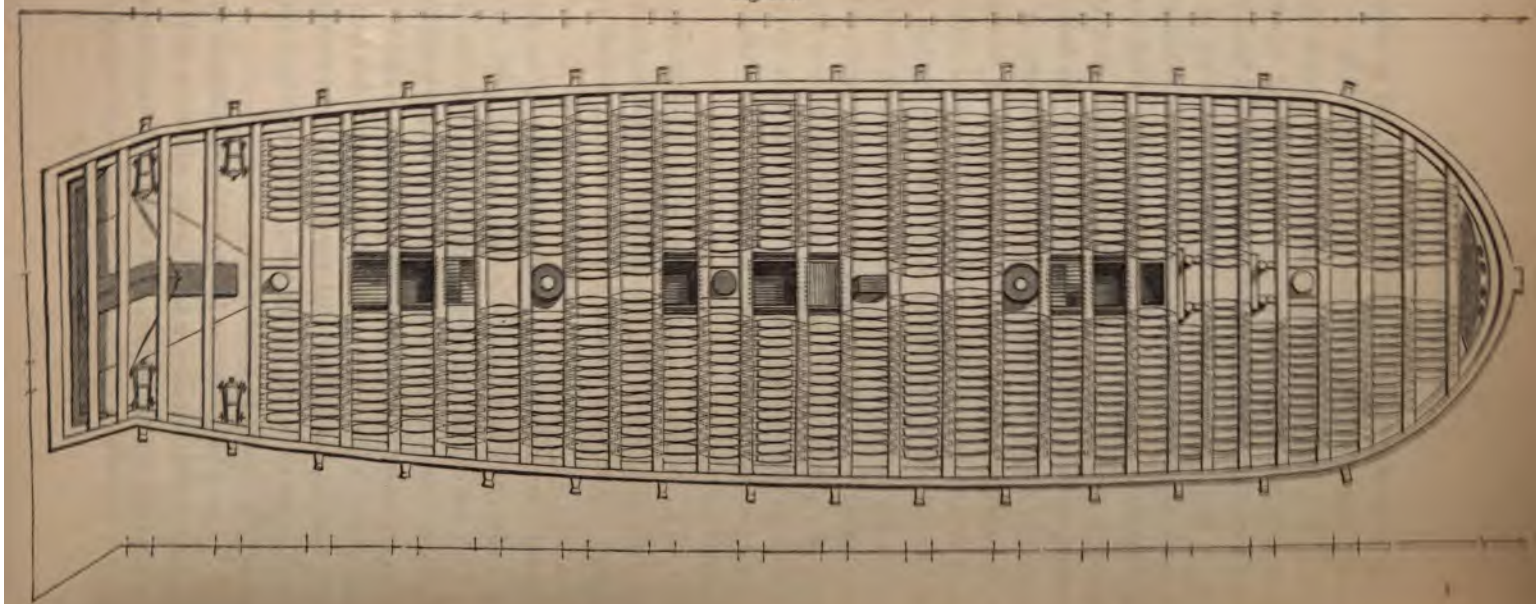
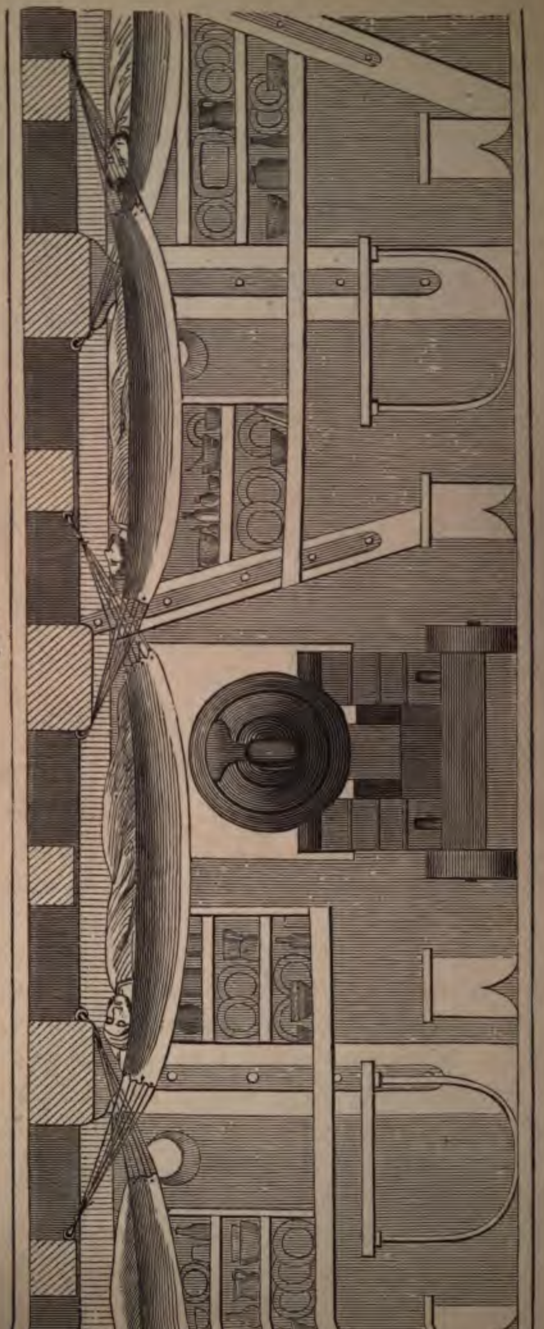


Fig. 264.



The small figures represent the individual hammocks, which are commonly so close to each other, that they form an impenetrable barrier to the progress of air between them, though air may circulate between their extremities in a very imperfect manner. Two, three, four, or five hundred men may be constantly observed in their hammocks, in the lower deck of a man-of-war, according to the duties that require attention at sea, or in a protected anchorage.

766. Dense as the aggregation of bodies may appear in the

Fig. 265.

figure shewn, it is short of the reality, as has been hinted, when the ship is crowded. The following figures shew more minutely the position in which the sailor sleeps. In Fig. 263, the middle deck is supposed to have been removed, and the sailors in the lower deck exposed to view, as they sleep in their hammocks, immediately below it. In the longitudinal section, Fig. 264, the proximity of the body to the beams above is shewn. In Fig. 265, a view is given of an individual hammock.

767. In numerous observations, taken in different ships, at all hours of the night, and under very various circumstances, I

have almost always noticed that the same fact, viz. that sailors do not enjoy a refreshing sleep when the lower deck is crowded with the usual complement of men, and the ports shut. Even when one-third or one-half of the men are not in their hammocks, still the space allowed for each does not, at ordinary temperatures, and with no special arrangements for ventilation, allow any adequate supply of air. In a few minutes, in general, after the men retire to rest, the atmosphere around them becomes saturated with moisture, and largely charged with carbonic acid and animal exhalations; even then, it is almost insupportably offensive to the majority of individuals accustomed to a better atmosphere, who place their head for a short time between the hammocks. It is not, perhaps, too much to affirm, that the premature old age which appears to creep insidiously upon the sailor who sleeps where such an atmosphere prevails, arises more from this cause than all the other hardships to which he is exposed, particularly when it is recollected that his natural sleep is broken by unequal watches, and that he is not unfrequently called upon to pass from this enervating and over-heated atmosphere, to encounter all the severities of the storm and the coldness of the midnight air.

768. Better arrangements for the sleep of the sailor are desirable accordingly, not only to enable him to breathe a purer air, but also to prevent the bad effect of those extreme transitions which are to many still more injurious than an oppressive atmosphere. There may be practical difficulties in the arrangement, but if a general discharge of vitiated air from the lower-deck could be effected, and the hammocks suspended at a lower level than at present by special arrangements, or converted into cots, the sailor would, at once, be relieved from the more injurious effects of such atmospheres, as the current of vitiated air, in whatever way it might incline, would then roll over at a higher level than his head, instead of enveloping his whole frame. The result of numerous observations made in various ships, from first-rates to the smaller iron steam-boats, has presented a difference of from 2 to 12 degrees between the temperature of the warmer

air respired and that of the floor of the deck, a few feet below. Such was the range, at least, observed in the Benbow (72 guns), in the Camperdown (120), and in much smaller vessels. And when the full complement of men have been present, the dimness with which the candle burned, and occasionally the oppression or restlessness of the sentry in particular situations, according to the manner in which he is affected, often indicated, in the strongest manner possible, the condition of the air.

769. By sleeping on the floor of the lower-deck, instead of in the hammock, great relief is in general immediately experienced; but the intermediate position is decidedly preferable, as there the sailor is equally protected from the first impulse of sharp and cold currents rolling upon the floor, and from the deleterious stream above.

770. In some parts of the lower deck, the air is generally much more offensive than at others, particularly between the hause holes (for the cables at the bow) and the foremast hatch. When these apertures (the hause holes) are well closed by those who are apt to suffer from being near to them, no circulation, between the hause holes and the first hatch, is observed, except of the most trifling description; and this is generally produced by an under-current passing forwards, and returning in an opposite direction above, so as to supply each succeeding berth with the atmosphere exhaled and expired in the preceding hammock. In seventy-fours, and other ships of this class, the atmosphere in the zone of respiration becomes generally very indifferent abaft in the course of a quarter of an hour or twenty minutes after the men retire to rest, and inundates the gun-room at the stern, a slow current passing commonly, though by no means always, throughout the whole ship from the bow to the stern.

771. When the lower-deck ports are open, or provided with window frames, as may be observed in the guard-ships at Sheerness, and two other stations, the purity of the air at night is greatly improved; and even in cases where, from the state of the weather, they have been professedly shut, still if they

are not closed with the care and precision adopted at sea, the minute infiltration of air that takes place produces a marked effect, and facilitates the expulsion of the vitiated air above.

---

772. In looking to the means by which ventilation may be promoted on board ship, openings working by the natural movements of the air,—The Windsail—the Steam-boat fire—the Gallie or other Fires—and the mechanical contrivances explained in Part II.,—all demand attention. But in tracing their effects, however useful they may prove in particular localities, it will be found that, without the systematic arrangement of air-channels, very local effects only are produced in large ships; and frequently the air extracted is not necessarily, in all cases, the vitiated air of respiration, but may, under certain combinations, be the pure air which may have only recently entered.

773. The WINDSAIL is a very valuable auxiliary on numerous occasions, and, indeed, for general use on board ship; but many serious objections arise when it affords the only means of ventilation that are accessible. It is usually made of canvas, and of a length sufficient to admit of its being extended from some height above deck to any deck (or hold) where its action is required. The open mouth of the windsail being turned to the wind, it enters freely, according to the force with which it blows, and the manner in which it is arranged.

1. It is of little or no use as the weather becomes more and more calm, *i. e.* on those occasions where ventilation is generally most urgently demanded.

2. In stormy weather, when the hatches are battened down, and the men crowded below, it is inapplicable.

3. Its operation is frequently very local, the air introduced often dashing in a current in one direction, instead of traversing with an equal and gentle flow the whole space where its operation is required.

4. The severity of its action is sometimes so great, that it is not unfrequently tied up at night by those in its vicinity below deck, though others, at a distance, may not have been affected at all by its operation.

5. Where special sources of impurity prevail, whether they arise from bilge-water, the state of the hold, or other causes, there the windsail too frequently introduces fresh air which dilutes the impurity in the chamber to which it may be led, but does not effect that certain removal of a vitiated atmosphere which is the first desideratum, and which is necessarily accompanied in all ships by the introduction of fresh air forced inwards by the pressure of the atmosphere.

774. The common windsail always operates by a *plenum* movement. Brass or copper windsails or cowls are sometimes fixed on deck, and turned from the wind; they operate by exhaustion, and cannot be made of flexible materials, as they would then collapse.

775. The FIRE OF THE GALLIE has occasionally been converted into a ventilating power; but, so far as I am aware, no general and systematic distribution of communicating channels has accompanied the application of this power. Nothing, however, more certainly tends to improve the atmosphere of a ship, than the influence of the gallie-fire, as it may be made to serve the same purpose as a shaft; but the objections to sustaining the fire at night, and the size of the communications required for effective ventilation, must prevent its being so extensively useful for such purposes as might be imagined. In all cases where I have endeavoured to apply its action, the objections made appeared to me sufficiently cogent to force me to give up the idea of trusting to it alone, as the effective means of inducing a sufficient amount of ventilation; but, though not resorted to for this purpose, its power should not be thrown away. By establishing a communication between it and the hold, or any part of the ship where ventilation may be more urgently required, a certain benefit may be always secured, which will be productive of much good, even where nothing else is attempted.

776. The freedom of access generally necessary around the fire, and the construction of the cooling apparatus, does not afford facilities for those large and air-tight channels, which are so essential for obtaining considerable power from any heating apparatus; the larger the area, however, and the more direct their access to the fire, or to any channel formed between hot plates, the greater is the discharging power. It is almost superfluous to observe, that all such air channels should be carefully protected by several folds of wire-gauze from the ingress of any spark, as without this there would not be a sufficient guard against the risk of accident by fire. The gallie-fire operates most effectually when it is supplied with air by air-tight channels, solely from the places to be ventilated; but this is incompatible with its use as an open fire-place.

777. In the temporary application of local fires on board ship, for the purpose of drying or effecting a change of air, much may often be done to render them more useful by studying the circumstances under which they are applied, and taking care that a distinct course shall be given for the ingress of fresh air to supply the fuel, and another for the discharge of the vitiated air, or products of combustion before they have cooled so far as to lose their ascending power. When this is not attended to, the cold air supplying the fuel descending through the same channel as that through which the escape takes place, the conflicting currents retard each other's progress; the vitiated air gets too cold, and often remains a considerable time, to the danger or annoyance of those who are near it.

778. Wherever ventilating apparatus—as PUMPS, FANNERS, SCREWS, WINDMILL VENTILATORS, and BELLOWS, have been employed, they have all been made to act beneficially, particularly in those cases where an exhausting power has been put on the hold. If the exhausting power be put on the hold, it acts with more general benefit to the ship than if directed upon any other point, particularly if placed in the well, all the air in the hold being allowed to communicate freely with it. Unless, however, systematic channels be introduced in the man-

ner referred to, the number of instruments must be increased in proportion to the compartments to be ventilated, or very local effects only can be anticipated.

779. What, then, is the desirable course to adopt on board ship? and what are the more prominent points that should regulate, in general, the systematic ventilation of ships?

1. It cannot be expected that this subject will be put on the best footing, unless a higher standard of health, of strength, and of length of life, be kept in view than prevails at present, making allowance for the great improvements recently introduced, and the comparatively high condition in which the health of the Navy now stands. The question has too often hitherto been settled by a summary reference to what the constitution can bear, rather than in accordance with the laws that regulate the tone and strength of the human frame.

2. An increased allowance of air must form the true foundation of improvement in all crowded vessels; without this no satisfactory progress can be expected.

3. Regulated and appointed channels for the ingress of fresh, and the egress of vitiated air, are essential. Without these, no systematic movement of the air can be induced.

4. A moving power should be provided of such force and dimensions as to control the condition of the air throughout the whole ship, capable of being worked independently of fire, and of being brought into powerful action, both in extreme calms, and when the hatches are battened down in stormy weather.

5. In moving the air, the primary object should be to act directly on the vitiated air, and secure its discharge, as then fresh air must enter and reach the lungs uncontaminated with that which is withdrawn.

6. Much may be done to promote natural ventilation, in moderate weather, by adjusting proper communications with the external atmosphere.

7. In new ships, by forming the necessary channels between the original timbers, a great saving of expense may be effected.

8. As a general principle, the vitiated air should never pass

from the hold, or any other place where it may communicate an offensive atmosphere to the cabins; but the power should be so arranged, that they should rather draw air down from the cabins than send any vitiated air to them.

9. In trading sailing vessels, loaded with goods, special provision should be made for the comfort of the men, by increasing the amount of ventilation where particular cargoes are shipped that contaminate the air. The sleeping-berths of sailors, in such vessels, are sometimes still more oppressive than in the navy.

10. In steam-boats for passengers, particularly on short voyages of a few days, the offensive smell of the bilge-water from the hold, which is still so frequently observed, ought, perhaps, no longer to be tolerated, as the means of ensuring perfect ventilation would be simple and economical, compared with the magnitude of the evil that would be overcome. The action of the paddles, as fanners, in calm water or rivers, and the power of the chimney, afford ample means of ventilating steamers in ordinary weather. But, as the paddles would not be so available in stormy seas, and as the free use of the power of the fire might be objectionable on account of the diminution, however slight, in the production of steam, which might result from any impediment to the supply of air to the fire, or from the action of air of an inferior quality, affecting the combustion, and as these circumstances concur with causes that diminish the ordinary supply of air, by the closing of the ports and hatches, —a mechanical power, worked by the steam-engine, is much to be preferred. A power sufficient to sustain a comfortable state of the atmosphere, in a steam-packet, would not, in general, produce a sensible effect in retarding the progress of the vessel.

780. A small fraction of the amount usually spent on mere decoration in steam-packets, if devoted to the purposes of ventilation, would give unspeakable comfort to all who are borne down by the smell of the intolerable bilge, and other accompaniments of a rough or stormy passage. To them the want of some

superfluous finery would be no loss compared with the substantial advantages of a fresh and wholesome atmosphere, the want of which too frequently causes delicate constitutions to brave the severities of an exposure on deck, from which they do not always recover, rather than be subjected to the polluted atmosphere, which they dread below. It would probably also tend to increase the profits of the proprietors, were they generally to ventilate their packets, by inducing many to take passages, with comparative relief, upon which they would not otherwise venture, and as it is possible, by such means, to reduce very much the severity of sea-sickness, when its occurrence cannot be prevented.

11. In ships of war, transports, and ships similarly crowded, the extreme value of space on the fighting decks, and the numbers aggregated at times within a given space, render a modification of some of the arrangements essential.

12. In hospital-ships, and in all ships proceeding to *localities dangerous* from the state of the atmosphere, the power of working with a *plenum impulse* should be given in fitting up the ventilating arrangements, with the view of communicating chemicals to the air, and producing a medicated atmosphere on board.

13. In many floating chapels, a peculiar arrangement (shewn afterwards) is desirable, otherwise the warm air in summer enters above the congregation, and passes directly outwards, the vitiated air being retained below from the comparative coldness of that part of the ship which is below the water-line.

14. In convict-ships, having a severe exposure, the inmates often suffer much from the manner in which the air strikes upon them from the ports or windows, and also from the vitiated state of the atmosphere which they respire when they go to rest.

15. Slave-ships too often exhibit the extremes of human endurance, in the most vitiated atmosphere perhaps to which humanity is exposed, as well as the fatal influence which it ultimately exerts. Cruisers, carrying a small portable ventilating instrument on board, would often find it useful in relieving the sufferings of the slaves.

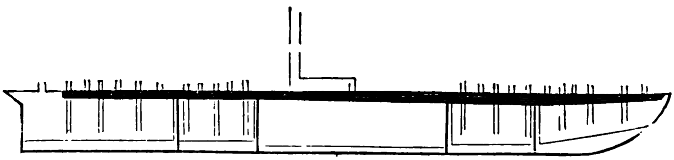
CHAPTER II.

ILLUSTRATIONS.

The following illustrations will convey a more precise view of many of the points referred to in connection with the ventilation of ships. They illustrate a series of investigations, made in ships of the line, steam-ships of war, yachts, packets, convict-ships, floating-chapels, &c. &c., in this country, and other places, more particularly in the Baltic.

781. In taking a general view of the ventilation of ships, let Fig. 266 indicate any ship, and let the broad dark line ex-

Fig. 266.



tending from bow to stern, point out a ventilating channel commanding the whole of the ship ;—the object is to draw off vitiated air from every compartment, giving the means of an equivalent supply of fresh air entering with such diffusion as prevents it from being offensive. If the under side of the tube that opens into the various compartments separated by bulkheads be connected with them by apertures commanding the atmosphere in them, then, any heated chimney, shaft, or apparatus on deck, whether of the form represented or very different, if it can secure a flow of air, draws from it the whole of the compartments, when the valves are properly adjusted. Fresh ir enters, at the same time, by the open tubes represented at

right angles to the other, and distributes itself over the floor before it escapes to the ceiling, where it is ultimately discharged above deck.

782. Again, certain tubes are seen in the above figure passing from the horizontal tube to the hold, but supposed in the case explained to be shut. But if the valves in them be opened, then the leading horizontal ventilating tubes operate not merely upon the compartments referred to, but also on the hold, as indicated in Fig. 267. And, if the apertures mentioned in the

Fig. 267.

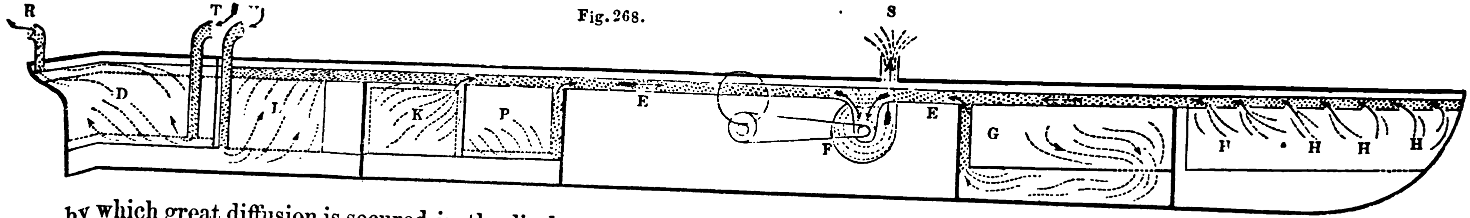
preceding paragraph be closed, those in the descending tubes to the hold being opened, the whole power of the ventilation can be placed on the hold alone.

783. Lastly, if the horizontal tube be left out of consideration, a certain amount of ventilation may be always secured by connecting two tubes with every compartment, the longer one leading fresh air to the floor, while the shorter one opens at the ceiling, and discharges the upper stratum of hot vitiated air from crowded and warm apartments. This latter arrangement of the ventilation is not supposed to be in any way connected with that explained in the two preceding paragraphs: it is the simple and natural mode, but not so effective as to be depended on; and one that is often rendered comparatively inefficient by the upper discharging tube alone being provided instead of two, for each individual cabin. More than two may be used for each place, as shewn, if one sufficiently large cannot be obtained.

784. In effecting the objects now adverted to, the power to be used, and also the leading air-channel, may be placed on deck, or below deck, and endless variations may be made in details, as local circumstances may dictate, if the proper amount of air be supplied with the requisite diffusion.

785. The accompanying figure represents the above arrangements, as carried into execution in a steam-boat, the ventilating power being placed in the engine-room and under deck. H H H H the forecastle, communicating vitiated air to the great horizontal channel under deck, by which it is ultimately cast out into the external atmosphere; G and P are other compartments in which the ventilation is effected from the hold, the air in G and P passing into the hold before it escapes into the horizontal channel, the ordinary apertures in G and P (such as are seen open in H) being shut; K an arrangement

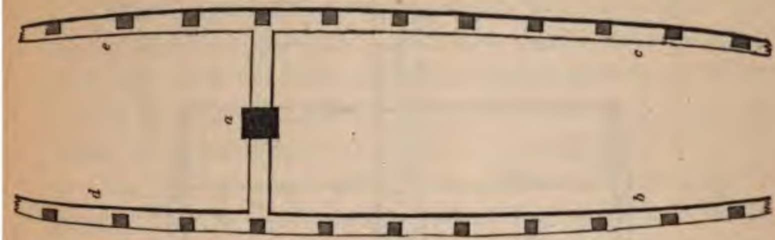
Fig. 268.



by which great diffusion is secured in the discharge of the vitiated air; L indicates an apartment supplied in another mode from the hold, an arrangement considered objectionable, in general, where miscellaneous stores are kept in the part of the hold represented, and advantageous in hot climates where the hold is perfectly clean and fresh, the vessel made of iron, and the water colder than the air; T D and R represent the most desirable mode of arranging natural ventilation in a cabin where it is required, the metallic cowl that admits air being opposed to the wind, and the other, which discharges it, being turned from the wind.

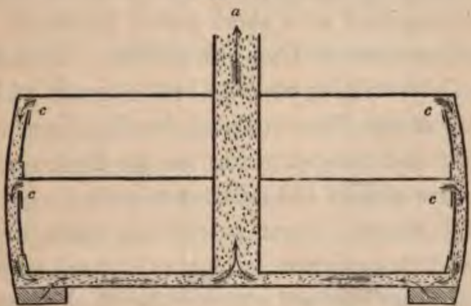
786. Fig. 269 shews a plan of the great ventilating channels in the hold of the Minden now in China; *a* the central commu-

Fig. 269.



nication which receives air from the two transverse tubes connected with it, and discharges it upon deck. These transverse tubes receive air from the fore and aft branches *b d*, *c e*; they

Fig. 270.



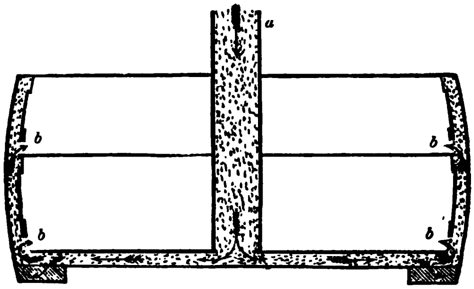
are secured along the side of the shelf, and connected with upright tubes wherever a dark mark indicates the position from which they pass into the decks above, as explained in the following section.

787. The section is taken across the centre *a*, and shews one series of its communications on either side. The air from the cockpit and gun-decks enters the upright tubes at *c c*, when the valves are opened, which can be adjusted to any extent that circumstances may require. A mechanical power placed in the cockpit-deck at *a*, commands the ventilation of both decks and of the hold, according to the openings in use.

788. In the event of it being considered desirable, at any

time, to medicate the air, the movements of the aerial currents can be reversed, and any peculiar products conveyed to the hold, or to the decks by the lower valves *b b*, Fig. 271.

Fig. 271.



789. The ventilation of the Minden was recommended by Sir William Burnett, the Inspector-General of Naval Hospitals and Fleets, and completed at a short notice, principally with such materials as the stores at Plymouth afforded. It is commanded by Captain Quin, forming also the head-quarters of Dr Wilson, the Inspector of the Fleet in China, &c. &c., and the author of the important and valuable report on the Health of the Navy to which I have already had occasion to refer.

790. The Minden, about twenty-four years ago, was the scene of one of those serious accidents that have occurred in the well,* and in other confined places on board ship; and such accidents having led me to recommend that every ship should be provided with a small portable air-machine, such as I procured at a future period for the Minden and other vessels, independent of the general system of ventilation introduced, it may be important to state briefly the details of the case, so far as I have procured them. I obtained the following account from Mr Miller, who was the master at the time the accident happened, of which he informed me several years before I ventilated the Minden, when attending my classes at Edinburgh. I

* The lowest part of the hold, to which all water entering by leakage or otherwise into the hold, always flows, and upon which the pumps are accordingly made to play. It is pointed out particularly in some of the following woodcuts.

have not been able to procure any information as to the peculiar nature of the gas evolved, as it was not made the subject of experiment; it was, in all probability, carbonic acid gas, from the effect it produced upon the candle, but might have been mixed with other products. The more speedy recovery of the first sailor, who had been longest in the well, and exposed to the gas in its most concentrated form, is not an unusual case, as those often suffer most who enter an atmosphere of very bad quality, if mingled with sufficient air to admit of its entering the lungs; while, if more concentrated, the individual exposed falls down in a state of suspended animation, without any reaching the lungs; and hence, if placed where he revives, he is the first to recover, his lungs being freest from bad air.

ACCIDENT IN H. M. S. MINDEN IN THE YEAR 1819-20.

"On board H. M. Ship Minden, bearing the flag of Admiral Sir Richard King, in the harbour of Trincomalée, in the year 1819-20, a boatswain's mate was ordered to see the pump well swabbed out. A man was accordingly sent down with a bucket and swab, but as he neither filled the bucket nor answered when called to, a second man was sent down to see what he was about. He also refused to answer immediately. Three more rushed down into the well, who all, like the first two, remained silent. It was then reported on the quarter-deck that the men in the pump-well were supposed to have got into the spirit-room. The master, on entering the cockpit, suspected the true cause of the men's silence, and ordered a lanthorn to be lowered into the well, the light in which went out when about half-way down. It was let down a second time, and the light burned long enough to shew the whole of the men lying over each other on the kelson. On being lowered down a third time, the light was found to burn dimly at about 6 feet above the men. The master, with a bowling-knot under his arms, descended the well, leaving directions to haul him up the moment he could not answer—he succeeded in slinging the men, who were hauled up and laid on the main-

deck, to all appearance quite dead. In a short time they began to respire, the lips and face became black; they foamed at the mouth, and the whole were fearfully convulsed. None of them recovered their usual health, and some of them were invalided. The man who descended the well first, was the first who recovered.

(Signed) "JOHN MILLER,
Late Master of the Minden."

London, December 1842.

Mr Miller has since added—

"The officers who assembled in the cockpit, on hearing what had taken place, remonstrated against the master descending into the well; but he replied that he thought he could breathe, at least, as low down as a light would burn, and on reaching the light he felt no inconvenience; and even after he had succeeded in slinging the whole of the men, though he was engaged for a full quarter of an hour, he did not subsequently experience any further inconvenience than a slight headache. From the agitation, the air continued to improve gradually in the well, and by the time he had left, the candle was not extinguished when lowered to the kelson (about 6 feet lower than it was capable of burning at first)."

Facilities presented for providing arrangements for Ventilation in the original construction of large Ships.

791. Though the influence of steam, and the use of very large guns and shells in ships of war, is daily introducing new peculiarities of construction in the naval service, it will not be unprofitable to consider the manner in which permanent arrangements for the ventilation of large ships, of the usual construction, may be secured, and temporary substitutes applied in ships already built. For this purpose, it will be necessary, in the first instance, to refer to the following figures.

792. Fig. 272 presents a section of an eighty-gun ship. A

Fig. 272.

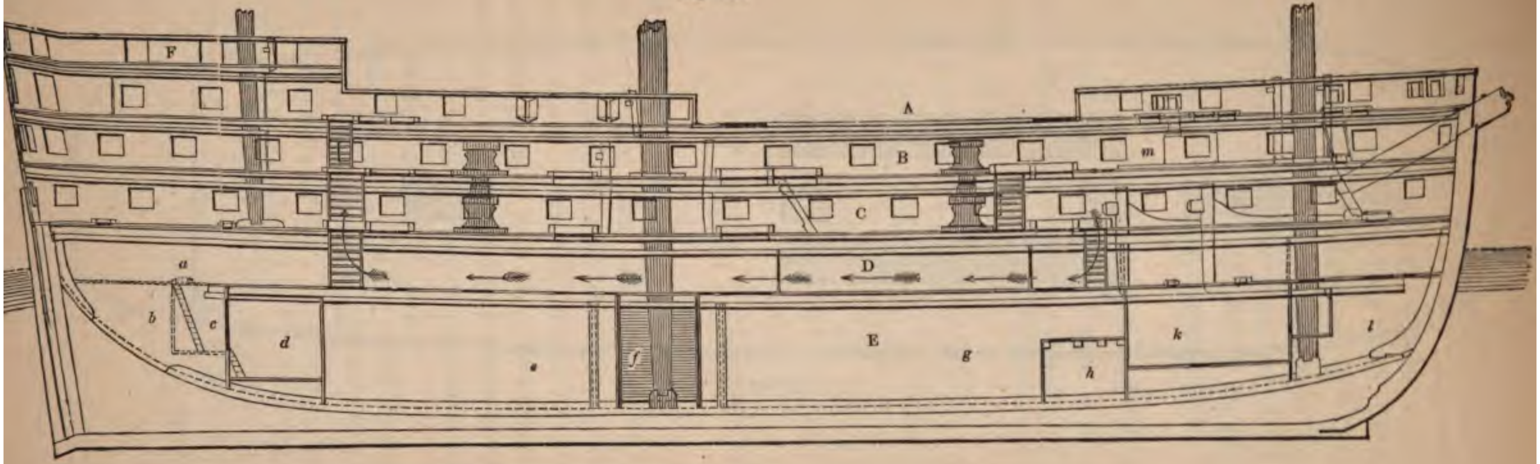
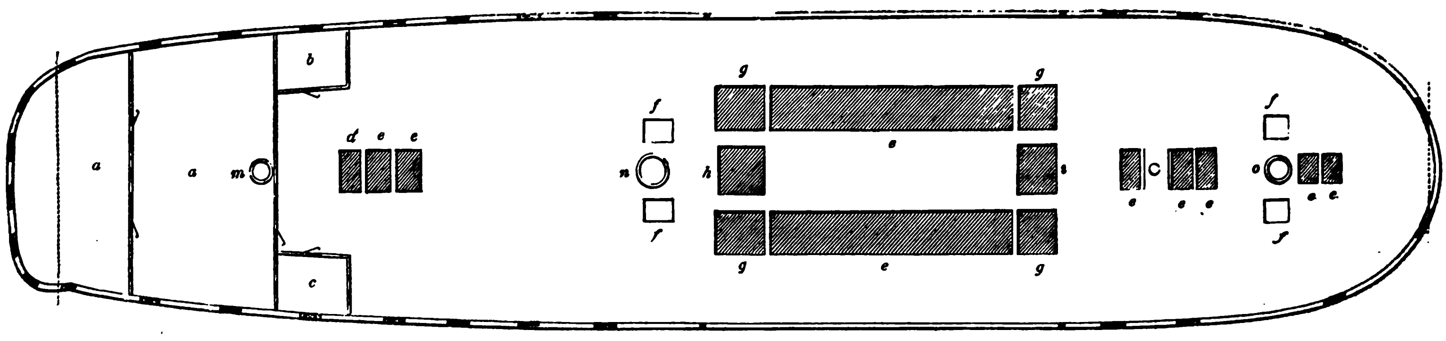


Fig. 273.



the quarter-deck and forecastle; B the main-deck; C the lower-deck, or gun-deck, bearing the heaviest metal; D the orlop or cockpit-deck; E the hold; F the poop; *a b* miscellaneous stores, bread room, &c.; *c* passage to the after magazine; *d* the magazine; *e* store-rooms, spirit-room, and after hold; *f* the well; *g* the main hold; *h* the coal-hole; *k* the principal magazine. The light-room is the compartment beyond it and *l*; *l* the gunnery store-room.

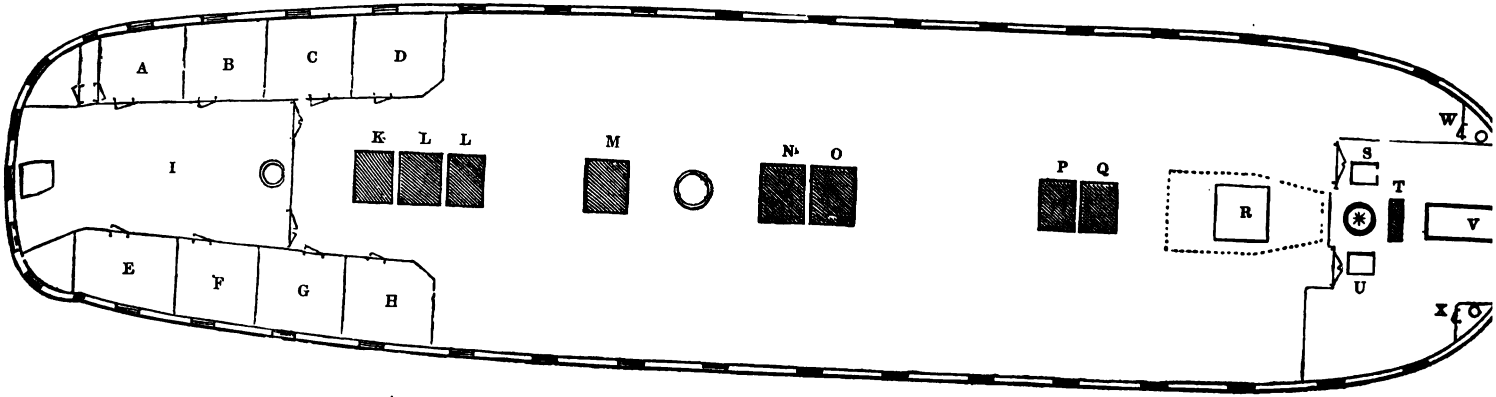
793. Fig. 273 shews the quarter-deck and forecastle of the same ship. *a a* the captain's cabin; *b c* the clerk's and captain's steward's offices; *d* ladder way; *e* gratings; *f f* scuttles; *g g* ladder-ways; *h* main-hatch; *i* fore-hatch; *m* mizenmast; *n* mainmast; *o* foremast.

794. Fig. 274 gives a plan of the main-deck; A the master's cabin; B the captain of marines; C the wardroom steward; D the third-lieutenant; E the commander; F the first-lieutenant; G the captain's steward; H the second-lieutenant; I the wardroom; K the ladder-way; L L gratings; M hatch; N main-hatch; O ladder-way; P ladder-way; Q fore-hatch; R the galley fire; S T U scuttles; V dispensary table; W X closets.

795. The boundaries enclosing S T U V X constitute the SICK-BAY or INFIRMARY, where improvements to a very great extent might be easily made in the ventilation, in the sleeping-berths and in the closet, by following the details explained in the general illustrations given in Part II. Here also the use of a special ventilating power, as a moveable fanner or screw, would be extremely useful, under particular circumstances, if placed at the disposal of the medical officer in charge.

Fig. 275 points out the gun-deck, where the sailors sleep, the various hatches and ladder-ways continued from above, and the gun-room at the stern, which I have formerly mentioned as being so often overrun with the vitiated air from the place where the sailors sleep. The arrows proceeding from *a* to *b* indicate the course which the air may be made to take, if the vitiated air produced by respiration be withdrawn by channels such as

Fig. 274.



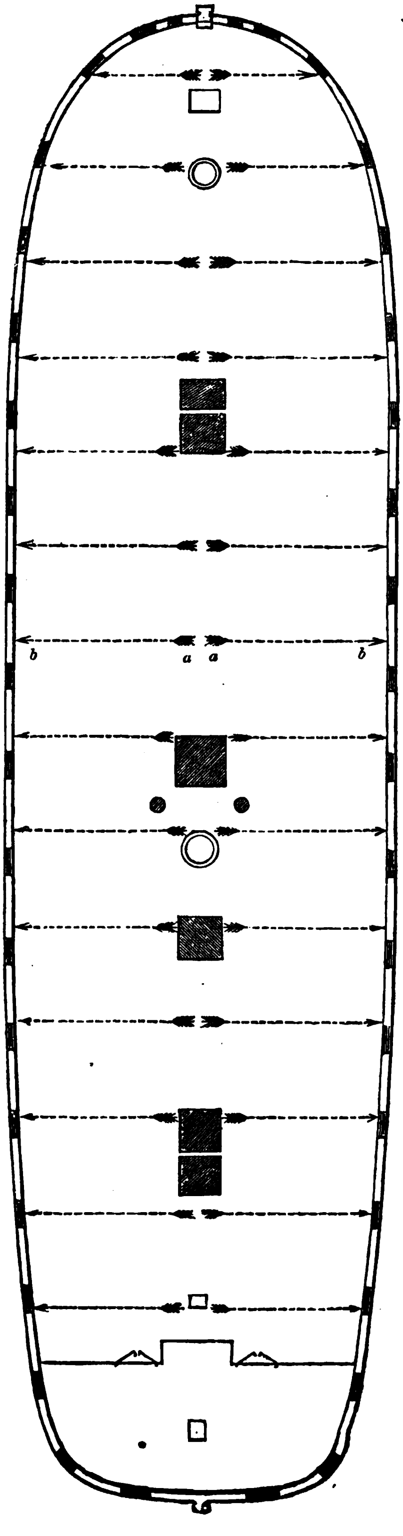


Fig. 275.

have been already represented in the figures explaining the ventilation of the Minden, where they were formed of iron tubes, or they may be constructed as explained in succeeding paragraphs.

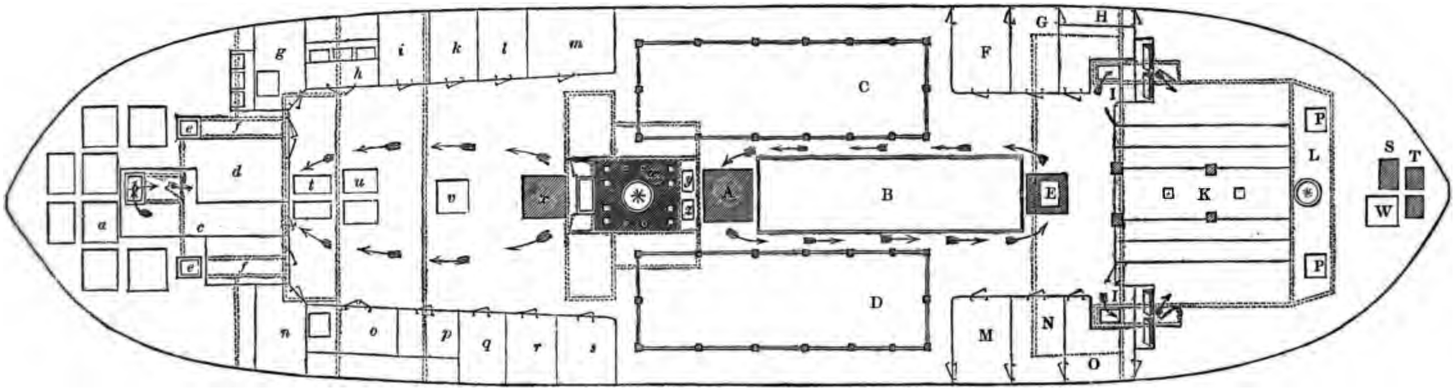
796. Fig. 276 gives a plan of the orlop or cockpit-deck. *a* One of a number of gratings, below and above which bread is usually stowed; *b* scuttle and passage to the after magazine; *c* the magazine passage and handing-room; *d* the after magazine; *e e* scuttles to the light-rooms; *f f* light-rooms; *g* purser's store-room and bins; *h* ward-room, store-room, and bins; *i* chaplain; *k* fourth lieutenant; *l* schoolmaster; *m* midshipmen; *n* surgeon; *o* captain's store-room; *p* dispensary; *q* fifth lieutenant; *r* lieutenant of marines; *s* second master, assistant-surgeon, and captain's clerk; *t u v* scuttles to store-rooms, spirit-room, and dry provisions; *x* the after-hatch; *y z* scuttles to shot-locker.

797. In this part of the figure, the reader's attention is particularly directed to the arrows proceeding from either side of *x*, which indicate the course in which fresh air supplied by a windsail through the hatches above traverses too frequently the centre of the cockpit, overpowering at times those who receive its direct impulse, even though it be checked before it escapes, and dashing impetuously, when the wind is strong, to the ladder-way above the scuttles *t u*, while those in the adjoining cabins have little benefit from it. The doors, and the structure of the frame, give no necessary ventilation at present, though, from the open spaces communicating with the timbers and with the upper part of these cabins, the deck above, and the hold, facilities are not wanting for the application of power.

Continuing with Fig. 276, *w* indicates the well; A the main hatch; B the sail room; C C cable tiers; E the fore hatch; F boatswain; G marine officer; H slop-room; I scuttle to the magazine; K the principal magazine; L the light room; M carpenter; N gunner; O pilot; P P scuttles to light room; S T W gratings and ladder-way to gunner's stores.

798. The arrows between the hatches A and E represent

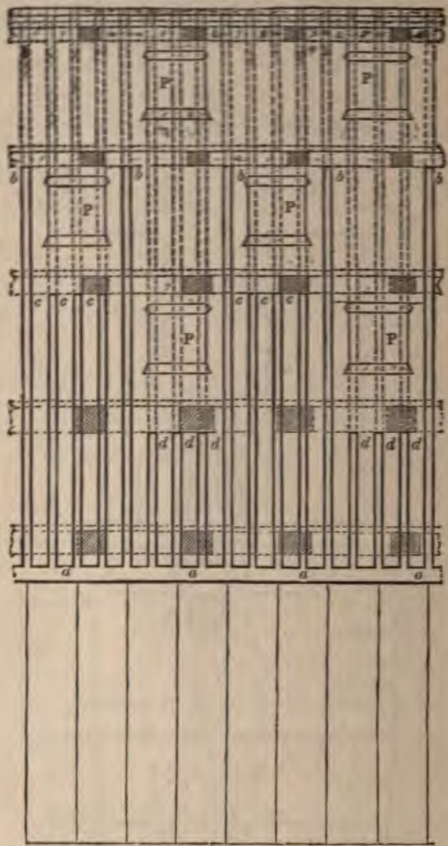
Fig. 276.



the movement of a circling series of currents that may be traced occasionally between them, very slight circumstances varying the inclination from A to E or E to A.

799. Fig. 277 points out the vacant spaces that are to be

Fig. 277.



met with at present in all first-rates constructed, or in the process of construction, which may be made available for ventilation. They exist comparatively useless at present, except in so far as they prevent the more rapid production of dry-rot by the amount of aeration which they give, however feeble and un*certain it* may be, as the air in them always vibrates or fluc-

tuates a little with the rolling of the ship, and the variation of temperature in the different decks and the hold. Minute and careful watching of the extent to which the air moves in them, has assured me, that the effect they produce at present is altogether trifling, though even that is valuable, in so far as it prevents absolute stagnation. In this figure, though another deck is seen beyond what is met with in the 80 gun-ship, the general disposition of the vacant spaces is the same in all; but if these are sufficient in the larger ship, where there is an additional deck (the *middle-deck*) to ventilate, it will be seen, on examination, that the 80 gun and other smaller ships, may be ventilated with no more difficulty.

800. As to the mode of using these vacant spaces, which are found between the timbers and the planks, it is explained by the figure. A horizontal tube *a a a a* is provided, in the first place, in the hold, as in the Minden (see page 369), and connected with the spaces selected for use. Thus, in the cockpit-deck, *d d d*, under the lower-deck ports, would carry air directly from the cockpit ceiling to *a*. In the lower-deck, *c c c* would perform the same office; and thus a ventilating power might be applied to the hold (by openings in *a*), to the cockpit-deck, and to the lower-deck, the places of all others which it is most important to ventilate, if an exhausting power were placed upon *a*, and a horizontal tube (such as *a*) provided on both sides, according to the amount of ventilation deemed expedient.

801. Even the middle-deck might be commanded to a certain extent, if necessary, as shewn by the tubes *b*; and this, in a first-rate, corresponds, in its distance from the hold, with the main-deck of the 80 gun-ship.

802. The dotted lines represent the supposed continuation of spaces that would become apparent, and extend in general to the quarter decks, were they not rendered ineffective by the cutting out of the ports, or by their being used at a lower level.

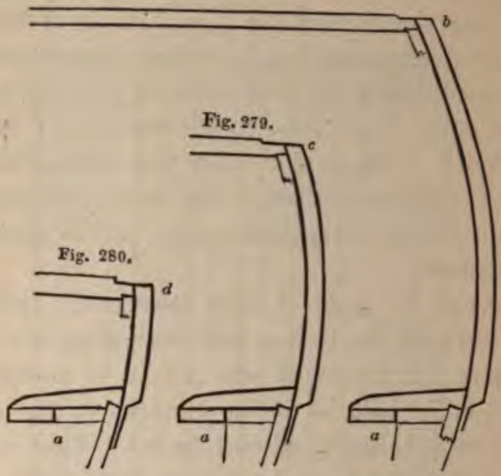
803. In Fig. 278, *b* gives a vertical section indicating the form of the tube represented by *b* in Fig. 277; *c* shews the

corresponding tube from the lower-deck, and *d* that from the gun-deck; *a* shews the horizontal iron-tube in the side in the

Fig. 278.

Fig. 279.

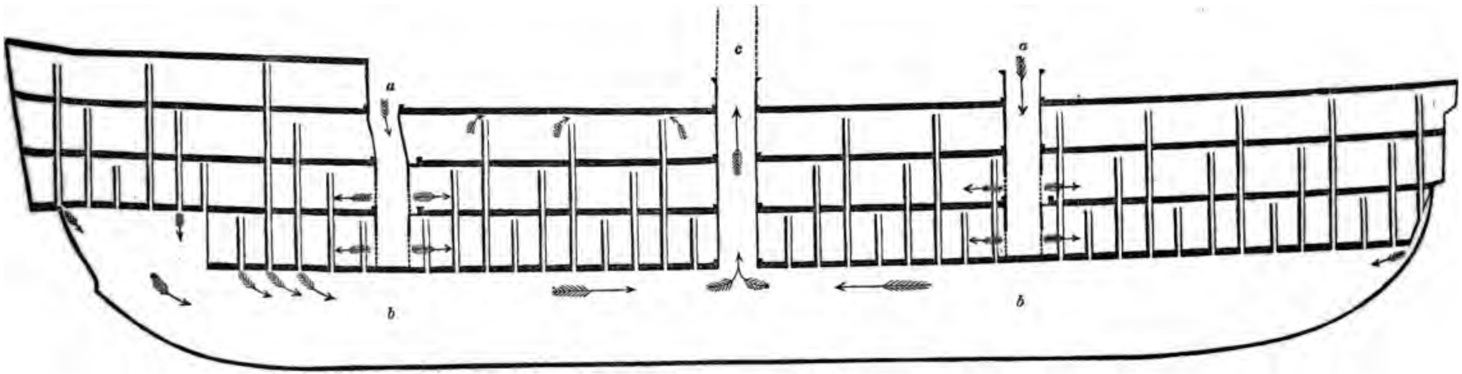
Fig. 280.



hold next the shelf, where it occupies the space of all others least valuable in the hold.

804. Again, Fig. 281 represents a very general explanatory view of the mode in which a ship in the East or West Indies, or in any other region where ventilation was very important, might be provided at once with a powerful temporary ventilating apparatus, were the system now adverted to carried out, no farther than so as to secure the discharge from the deck into the hold by proper valves, and opening and regulating the number brought into play in a given time. This figure is supposed to represent a ship in which every thing at the hatches is moveable; and were these converted into supply and discharging shafts when the sailors are asleep, *a a* admitting fresh air, and diffusing it over the decks below the level of cots or hammocks, the small tubes conveying vitiated air from the ceiling to the hold, and the main hatch *c* being used as a shaft for the discharge of foul air, the whole ship might be kept comparatively comfortable even in a warm atmosphere; and in the

Fig. 281.



course of five minutes, every thing might be returned or removed, so that no one unacquainted with what was in operation could perceive afterwards that any thing unusual had been going on. The fresh and foul air channels in the hatches might be formed by a man, at every place where it was requisite, fixing painted canvas, made to fit the hatches, on every side; and the mechanical power used for ventilation might consist of a windmill ventilator, all the parts of which could be fixed or unfixed in a few minutes, occupying, when laid aside, but very little space, from the facility with which the blades could be arranged upon each other.

If then, by such simple means, a temporary but effective control could be obtained in moderating the severity of that atmosphere, whose power within the tropics is usually described as being so overwhelming, that it is difficult for any one to conceive the condition of the air which a sailor often breathes, when in his hammock, in the lower deck of a ship of the line, it may, in the next place, be inquired whether it would not be proper and advantageous to introduce permanent arrangements, which could be used for removing the vitiated air by distinct channels, such as have been superadded to the Minden, page 369, and to intertwine with the original construction of new ships, channels that may be equally effectual, though found generally between the timbers. There is no difficulty as to the principle or practice; the only questions are the extent to which such ventilative power is desirable, a question which has already been adverted to in another part of this book. (See Part I.) The details shewn in former figures, and in those that succeed, point out the more important points that can be adverted to, without entering more minutely into professional details than is consistent with the object of this work. The four following illustrations will assist in placing some of the points, bearing on the ventilation of large ships, in a more specific form.

805. If air be received by a ventilator turned towards the wind *g*, Fig. 282, and be discharged by another *a* turned from the wind, then, whether it traverse the deck *d e*, or *f*, the accu-

mulated products of vitiated air will act oppressively on any one where the decks may be crowded, if he sleep near the beams where the air escapes, and air from the hold may or may not contaminate the air in the decks above.

Fig. 282.

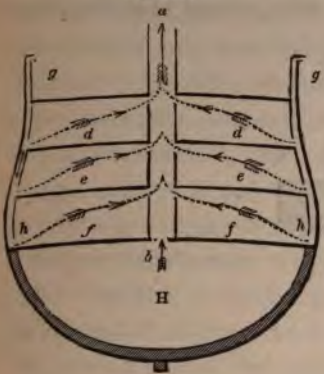


Fig. 283.

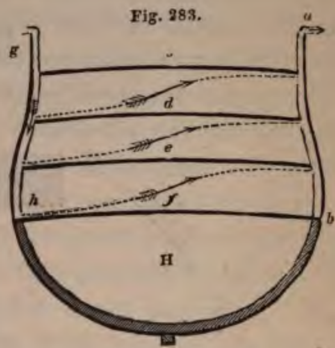


Fig. 284.

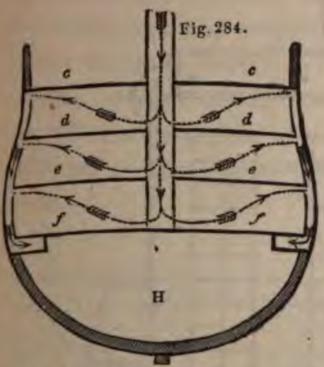
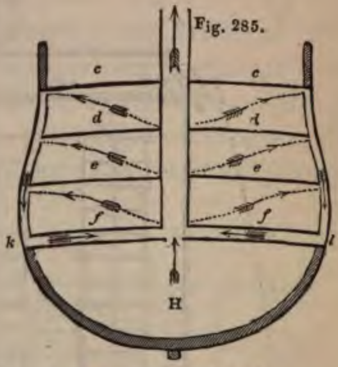


Fig. 285.

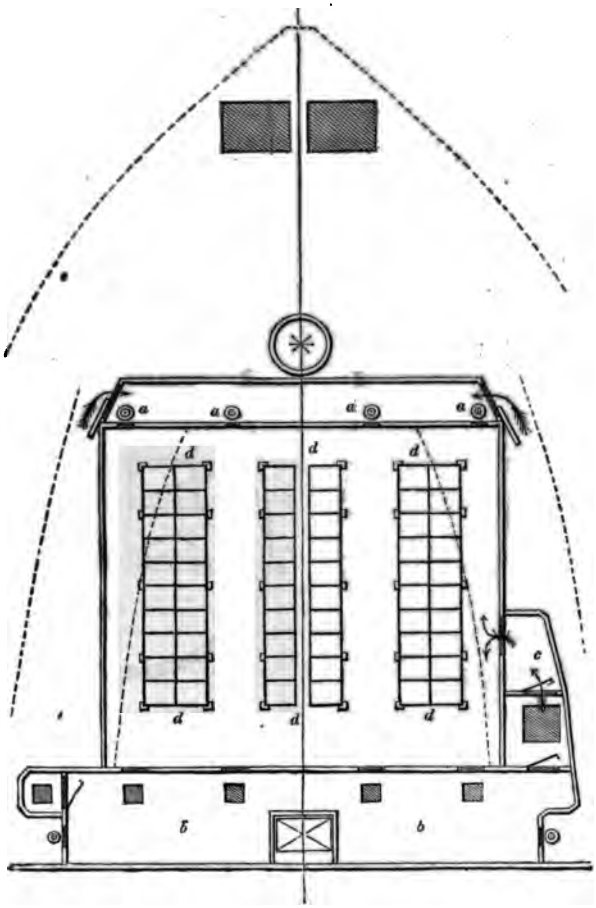


806. If a temporary discharging-shaft be rigged in the manner recommended, not only will it present a power and certainty which can never be depended on in the manner shewn in the preceding figure, but the vitiated air from the hold H will also be entirely under control, from the influence of the shaft upon it.

807. A shaft, however, fed with vitiated air as shewn in Fig. 282, is liable to the great objection, that its action is, in many respects, unequal; and, accordingly, the system shewn in the Figs. 284, 285 is preferred, these being transverse sections of

the shafts for the ingress of fresh air, and the discharge of vitiated air, when rigged for a temporary purpose to act powerfully on the whole of the ship. The air entering by descent is admitted to any deck in the proportion required, and escapes by the channels in the sides to the fore and aft tubes in the hold. These fore and aft tubes in the hold communicate with central branches placed

Fig. 286.

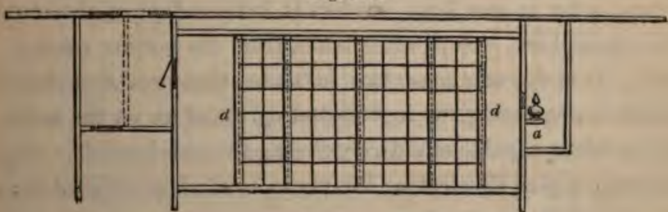


athwart ship, and terminating in the central discharge. A valve in the hold regulates the discharge from it.

808. Each individual opening being provided with a valve, the power of any machine can be cut off or put on at pleasure, and regulated to any extent that may be deemed desirable, according to the size of the channels, and the force put upon them.

809. The ventilation of the magazine is a subject of considerable importance, as cases have occurred where able-bodied and powerful men have fainted in it, from the extreme vitiation of the air. Security from accident being a primary object in any place, especially on board ship, where forty tons of gunpowder may be accumulated, every thing done for the ventilation of such a place must be in unison with this great essential. It is also an object to take no more air through the magazine than may be necessary when powder is exposed and assorted for such purposes as are required, as certain states of the atmosphere communicate an amount of moisture to it which is always prejudicial. Fig. 286 gives a plan of the disposition of the principal magazine in an 80-gun ship; *a a a a* the light-room, from which the light penetrates into the magazine through strong plate-glass windows; the doors leading to the light-room are approached by an external passage having no communication with the magazine; *b b* the receiving-room, into which the powder is handed from the magazine; *c* the passage into the magazine; *d d d* the powder-racks.

Fig. 287.



810. Fig. 287 shews a section through the receiving-room, the powder-racks, and the light-room.

811. So far as I have had an opportunity of visiting the magazines of different ships, at sea and on shore, and of ascertaining the various circumstances under which they are served, it appears

to be desirable that means should be provided for changing the air to a limited extent by propulsion, so that air can never be vitiated to the extent that has sometimes occurred. For this purpose, let a tube be provided below the magazine, or at some convenient place where it can be supplied with air from that part of the ship where it can be protected to any extent desirable, and let a small pump, bellows, or other instrument composed entirely of wood and copper, be placed near *a*, so that it can be worked gently from without, according to any pre-arranged signal, the air, forced in by a plenum movement, passing through folds of copper-wire gauze, multiplied to any extent in the ingress tube, which can also be prolonged by giving it several turns, if necessary. The air thus conveyed to the interior of the magazine will find a readiness of escape by the constant opening of the door or other communications with the receiving-room, and, on particular occasions, when the men are making cartridges, a special discharge *b*, may be put in operation, through which the air escaping must always tend to repel any spark, and not permit its return.

812. It is a mistake to suppose that it is very important always to have the least possible change of air in the magazine, as, when loaded to a certain extent with the moisture of the breath, that will affect the powder to a greater extent, in many cases, than the fresh air introduced. But the mode in which the gunpowder is now kept, renders it independent of the state of the atmosphere, except when taken from the powder cases.

813. It is scarcely necessary to state, that provision should be made in regulating the ingress and egress of air at the magazine, by valves capable of entirely closing the air-channels. Fig. 289 shews a plan illustrating the progress of air if diffused so as to move directly across the magazine.

814. In the magazine light-rooms, the supply of fresh air is often very insufficient; in some of those which I have visited, I have found the precipitation of charcoal in a minute impalpable powder (lamp-black) to be extreme, and occasionally the entire surface of the copper lining of the light-room was covered with

charcoal from this cause. Some modification of the lamps, or in the system of supplying air, as by securing a certain amount of

Fig. 288.

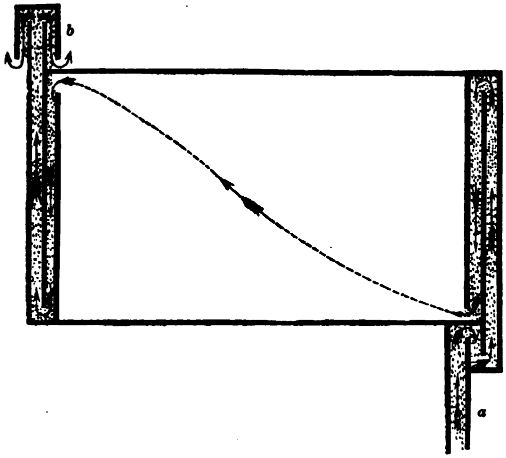
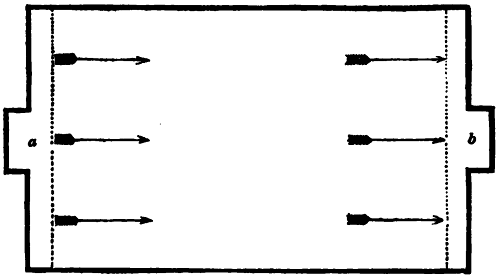


Fig. 289.



ingress and egress of fresh air through wire-gauze at the door, is certainly required in such instances as are now mentioned.

815. A short examination of the three following figures, shewing a profile and plans of a ten-gun brig, will explain their general structure, and point out that such vessels can be treated in the same manner as those already made the subject of observation. Fig. 290 shews the profile; A the bread-room, B captain's cabin, C passage, D gun-room, E pantry, F dispensary, G for the ship's company, Z the galley, H the cook's cupboard, K the captain's store-room, L magazine passage, M

Fig. 290.

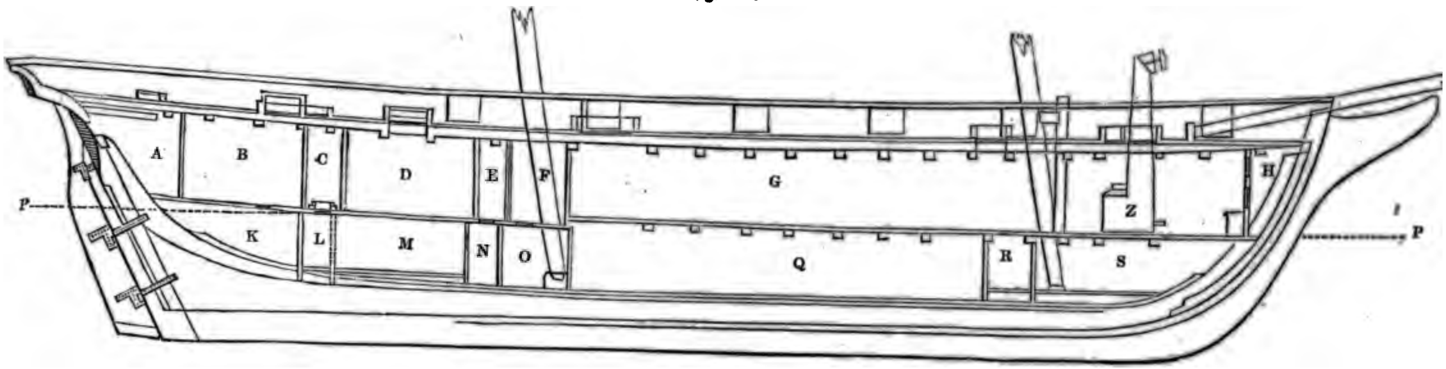


Fig. 291.

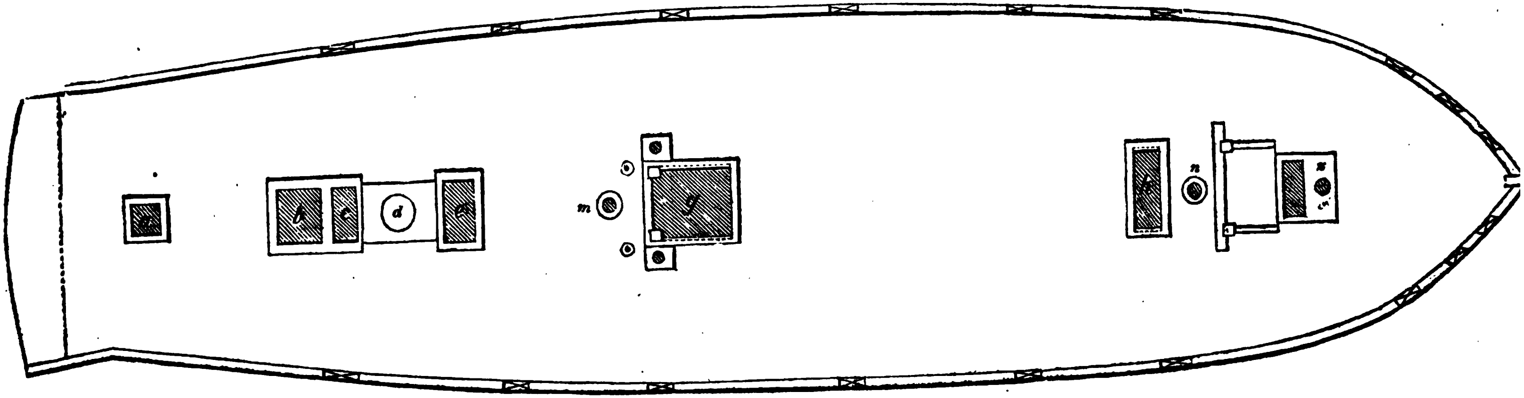
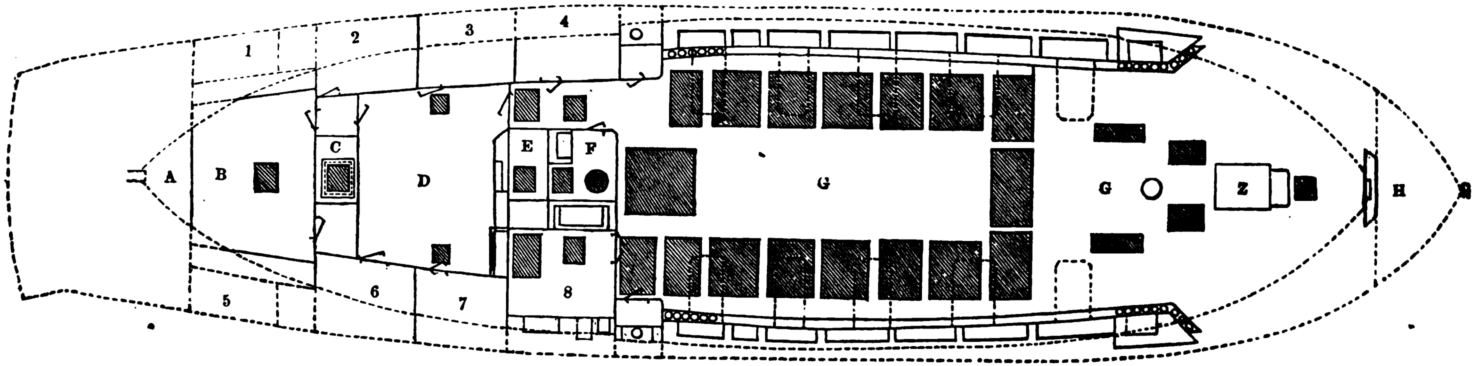


Fig. 292.



magazine, N light-room, O the well, P the water line, Q the hold, R the coal-hole, S carpenter's and boatswain's store-room.

816. Fig. 291 gives a plan of the upper deck; *a* scuttle to bread-room, *b* sky-light, *c* ladder-way, *d* capstan, *e* sky-light, *m* the main-mast, *g* main-hatch, *h* ladder-way, *n* foremast, *z* funnel from gallie.

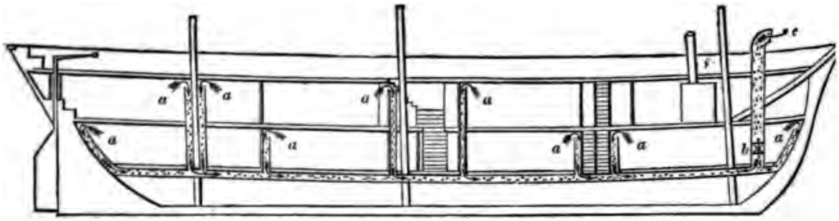
817. Fig. 292 gives a plan of the lower-deck; A captain's cabin, B scuttle to store, C scuttle to the magazine, D gun-room, E lieutenant's pantry, F dispensary, G for the ship's company. The dark figures shew the main-hatch and scuttles to the hold. The dotted lines represent the site of the tables; Z the gallie, H the cook's cupboard; 1 and 5 shew two bed places, lockers, and drawers; 2 the captain's steward's cabin; 3 the master's; 4 the assistant-surgeon's; 6 clerk's in charge; 7 mate's; 8 midshipmen's.

818. In examining vessels, such as ten-gun brigs, it is impossible not to observe, that, unless a ventilating power be used, and means given for enabling it, by a system of air-channels, to bear upon the different compartments represented, that amount of control over the atmosphere which would prevent it from being so notorious as it has hitherto been, cannot be obtained. Great improvements might undoubtedly be made by a series of openings along the deck, but the objections to these in stormy weather would be so great, that they could not then be used, however valuable they might be at other times. In calm weather, between the tropics, when the temperature within and without the ship is nearly the same, such openings would have little or no power, even though a considerable difference might be made in the altitude of those for the ingress, and those for the egress of air.

819. In Fig. 293, the horizontal tube in the hold, communicating with the descending branches from every separate compartment, viz., *a a a*, &c., the machinery for extracting air at *b*, and the channel for the discharge of vitiated air *c*, represent the great essentials of ventilation for vessels of the size now referred to. The screw, the fanner, or the windmill ventilator may be employed, as local circumstances may dictate. The moving

power *b* may be in the centre (in the well), or in any other position that may be preferred; the amount of ventilation given to

Fig. 293.



each compartment can be regulated by valves. From the hold, the vitiated air can be extracted by a valve in the lower part of the horizontal tube.

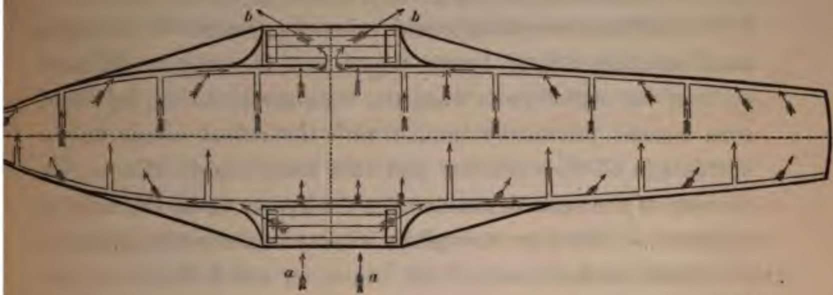
820. The horizontal tube in the hold may be made perfectly air-tight, and constructed of iron or other materials, such as are both air and water tight, so that, with a little management, its power, both upon the hold and upon the individual compartments, can be sustained without interfering with the use of water-tight bulkheads, where they are required for the safety of the ship.

821. In some ships, the amount of vitiated air produced is so great, and the circumstances so peculiar, that I have, on more than one occasion, found it necessary to introduce a plenum movement as the only certain mode of supplying fresh air to some of the cabins.

822. In paddle steam-boats, plying solely on rivers, and in all such steam-boats, when they are in smooth water, the paddle wheels may be used as ventilators, performing all the functions, as they are commonly constructed, of large fanners. A considerable number of trials have assured me of their power in this respect, and in some steam-boats, permanent provision has been made for using this power in smooth water. It will be obvious that paddles move the air as well as the water upon which they strike, and hence their power. The paddle, accordingly, when not interrupted in its action by a rough sea, or by the force of the wind, draws in air at the centre, and discharges air at the cir-

cumference. When the water in which a steam-boat moves is pure, it would not be difficult to have the advantage of the cooling power of the water, in sultry weather, brought to bear upon

Fig. 294.



the air supplied to the cabins, in the manner represented by Fig. 294, *the supply* being taken from the circumference of the paddle on one side, and the discharge effected through the centre of the other.

823. To afford greater security against the introduction of water, the air might be conveyed to the top of the paddle-box, and descend from this point to the centre. All such arrangements with the paddle ought to be viewed solely in the light of temporary expedients, not desirable as permanent arrangements even for river steam-boats.

824. In the engine-room of steam-boats, the excessive heat would be greatly diminished, and the atmosphere maintained in a more uniform condition both for the men and for the engine, while the smell from it would be much more under control, were the air admitted at the greatest distance from the fire-place, and made to traverse the engine as it passes to the boiler. At present, the cold air too often descends abruptly in front of the fire; the firemen are subjected to a precipitation of cold air upon their heads when perspiring profusely; *and the fires being supplied with sufficient air by the openings near them, those at a distance do not admit air, but often discharge vitiated air to the annoyance of the passengers.* It would not

be desirable, in every arrangement of engine and boiler, to cause the whole of the air admitted to traverse the engine; but, in the greater number of cases which I have seen, the arrangements were such as might have been altered easily, with considerable relief to the firemen and engineers, as well as to the passengers. If the intelligent engineer would take the trouble of holding a small smoking roll of brown paper (not flaming) in different parts of the engine-room when the fires are in action, he would soon become practically familiar with the actual course of the currents in all their details; and this being known, the precise position of the most desirable sites for apertures would soon be apparent. There are few places where, from the disposition of the planks on deck, and of the beams on which they rest, diffusion can be more easily given, and where it is more wanted than in the engine-room.

825. In calm weather, a temporary connection established between the engine-room and the paddles, exhausts all the foul air with rapidity from the engine-room, and would accordingly interfere with the amount of air supplied to the fires, and affect the production of steam to an extent highly objectionable, if not tempered in its action by a valve.

826. The ventilation of steam-boats may be effected entirely by the engine-room, the fire being fed by the air from the different places ventilated. This is not considered, in all cases, so desirable a mode of proceeding as might be anticipated, as the free and unfettered supply of air to the fires is sometimes of great importance in sustaining the speed of the engine. Cases have occurred where a steam-ship of acknowledged slow speed has, after a new and skilful disposition of the channels for ingress of air, proved superior to another that always sailed faster previously. In one of these the alteration was made, so that the air entered by the bows and pressed upon the fires. Hence, in calm weather, the faster the ship went the greater the force of the current entering as from a bellows, and sustaining the fires with more power than they could otherwise acquire. It will be obvious that every impediment to the facility of the

supply, independent of any deterioration of quality in the air, must affect the combustion. But where the fires are powerful, and the air freely supplied by the ventilating apertures, numerous steam-boats might use this power with great advantage; and in some, experience has proved that it is sufficient, though the want of adjustment, and of horizontal and perpendicular air-channels communicating with different compartments, has prevented it from being applied in the most advantageous manner. In guard-ships, moored at special stations for a long period, the crevices around the windows sometimes fitted up in the lower-deck ports, as at Sheerness, Plymouth, and Portsmouth, contribute much to promote the ascent of vitiated air from the place where the men sleep, and to give a more equal ingress of fresh air.

In Stationary Convict Ships, the means of effecting systematic ventilation might be introduced with great facility. The principal desiderata are,—

1. A regulated ingress of fresh air, supplying pure air to each deck.

2. A vitiated air-channel from each deck, discharging the bad air without sending it previously, as the only supply, to other decks.

3. The reunion of all the discharges in a central escape, controllable by a valve, so as to be regulated to any degree that the numbers in the ship, the state of the atmosphere, and other circumstances, may render necessary.

4. The introduction of a screw, or of a windmill ventilator, in the escape, that ventilation may be insured in all states of the atmosphere. In sultry and oppressive nights, one of the convicts turning the windmill ventilator would give great relief to all.

827. The arrangement now explained would have the great advantage of permitting systematic ventilation to such an ex-

tent as might be required even in the severest weather; while, no air being permitted to enter at windows or ports, those nearest them would be less subject to attacks of cold, such as may prove ultimately fatal in particular constitutions, not guarded against the ingress of air. The usual apertures around the crevices of the window might be rendered absolutely air-tight, the supply from other sources being ample.

828. Figs. 295 and 296 indicate the progress of the air in a convict ship, in which I examined very particularly the move-

Fig. 297.

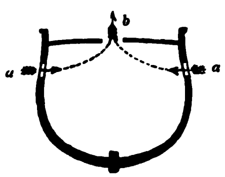


Fig. 298.

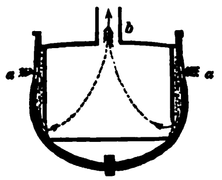


Fig. 296.

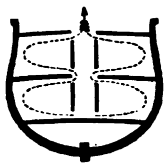
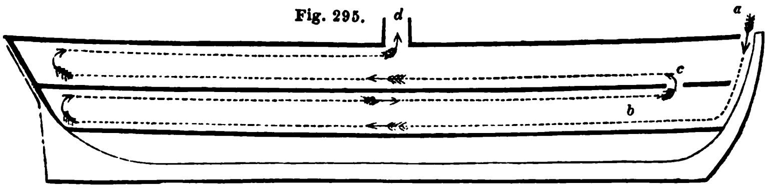


Fig. 295.



ment of the currents on one occasion, from the time the men went to rest till they rose next morning. Those nearest the ingress of the air on the lower-deck had good air, but rather in excess,—those a little farther on were comfortable,—the heat of the air warmed below by the respiration of the men, and by their bodies generally, gave it an ascensional power which enabled it to exclude fresh air from the deck above. Those above accordingly respired, as the arrows indicate, vitiated air from below. All, except a few, respired bad air.

829. Fig. 297 shews the progress of the principal currents of air which I have observed in hot weather in FLOATING CHAPELS. The external air, which was very warm, entered above the heads of the congregation at *a a*, and escaped at *b*.

The heat of respiration did not enable the vitiated air evolved to rise above it. The ship accordingly retained the vitiated air. Had arrangements been made, such as are shewn in Fig. 298, a very trifling power applied at *b*, or even the effect of a powerful sun acting on *b*, after painting it black, might have sustained a discharge. The air was heavy, dull, and disagreeable, during the whole service, when I made the observation I have explained.

CHAPTER III.

VENTILATION OF THE NIGER STEAM-SHIPS.

830. THE system of ventilation adopted in the Niger expedition, not only included the general arrangements recommended for the ventilation of ships, but additional means were also provided for controlling, to a certain extent, the influence of the atmosphere, and adapted to the peculiar service in which the expedition was engaged.

831. In particular, when I heard that ships had left the port of London for Africa, in which the deaths on a single voyage had been 80 per cent. (twelve out of fifteen having died, on an average, in many successive ships), I did not consider myself justified in limiting my suggestions merely to ordinary ventilation, but recommended that some attempt should be made to influence the state of the atmosphere to which the men might be exposed during the passage through the Delta. With this view, an instrument was devised, and materials procured, capable of producing a marked effect on various impurities frequently associated with atmospheric air, and on such ingredients as were expected to be met with.

832. This piece of apparatus was generally termed the Medicator, and in it the air could be filtered from mechanical impurities, influenced in its hygrometric condition, or charged with gaseous chemicals, capable of communicating a peculiar condition to it, or of neutralizing the influence of different poisons which have been found in it. The medicator, therefore, was a power that could be applied in all situations where it might be able to induce a special effect upon the air, as explained in

the subsequent paragraphs, but it never was proposed, as some not connected with the expedition appear to have imagined, viz. *as a certain antidote to an unknown evil.*

833. Few individuals, excepting those who have visited warm climates, are ready to credit the great supply of air that is indispensable for health and comfort in such countries,—the all-subduing influence, to many constitutions, of sudden or extreme changes in the quality of the air that surrounds the person, by the subversion of the previous balance that existed between the internal organs and the surface of the body,—and the extent to which the mental faculties, as well as the bodily strength, are often prostrated by such causes. Proceeding on the assumption that no supply of air that was likely to be provided by artificial means would exceed the wants of the system in the Niger Expedition, the demand made in respect to the power of the apparatus was limited solely by the opportunities accorded for giving effect to the arrangements proposed, and when their extent became the subject of special remark, my reply, on board these ships, while they were still at Liverpool, was, "that even if the whole ship were appropriated for ventilation alone, it would not be possible to guarantee a certain result, as the quality of atmosphere at the Niger had never been made the subject of experimental examination, and still less the precise nature of the evil which proved so fatal in former expeditions. It was therefore essential to have power; but the extent to which it ought to be used, and the various details to be insisted on under local circumstances, could only be determined upon the spot.

834. In my remarks on the ventilation of the Niger steam-ships, printed in the Friend of Africa, copies of which were placed in the hands of all the officers of the Expedition, I stated —"It must be obvious, that it will be impossible to estimate precisely the extent to which such an apparatus may prove beneficial, until some specific information, as to the peculiar chemical qualities of the atmosphere of the Niger, shall have been obtained." But so far as I can venture to form an opinion, I think Dr M'William's Report appears to justify me in saying,

that, though the magnitude of the evil was such that it could not be overcome, the medicator proved a useful medium in affecting the atmosphere of the ship with such materials as were introduced into it, and that there is reason to believe, from the nature of the agents employed, that they must have lessened the oppressive influence of that atmosphere.

835. I have appended, in full, a copy of Dr M'William's Report, and an extract from a letter from Captain W. Allen; and I beg to refer those who may take an interest in this question, to the Report presented to Government by Captain Trotter, to Dr M'William's Medical History of the Niger Expedition, and to Dr Pritchett's account of the African Remittent Fever, for details as to the history of the ventilation, which the limits of this work do not permit me to quote.

I may be permitted, however, to make the following brief remarks in connection with the history of the ventilation, and the application of the medicator.

836. When the medicator was recommended, there was an impression that the poisonous atmosphere might perhaps be passed through within a very limited period, and that, if the observations made on board the ships should lead to any discovery of its nature, then, should it have been amenable to the action of any of the chemical or mechanical agents supplied in conjunction with the medicator, the time would have occurred for steaming with the greatest possible rapidity, for placing as many of the white crew under deck as the duties of the ship would permit, for giving no more air below deck than was imperiously demanded, and for charging that air with such materials as might have been deemed advisable, and putting in action the full power of the medicator. No such circumstances, however, presented themselves, and the general use of the medicator was alone resorted to—all that could have been expected to be done under the circumstances. But while the air appeared salubrious beyond expectation, the fever suddenly and unexpectedly manifested itself in all the vessels, as will be seen on reading the following extracts from Dr M'William's work :—

"September 2.—The evening was beautiful, and the effect of the whole scene was that of general exhilaration, with a feeling of thankfulness and gratitude that we had advanced thus far on our mission with the whole of the crews in the enjoyment of perfect health."—Page 69.

"Up to this time the expedition had been fortunate beyond all expectation. The Delta had been passed, and we were entering the valley of the Niger under circumstances seemingly the most auspicious. The crews were in the best possible condition, and, with a general buoyancy of feeling, looked forward to the period when the vessels were to ascend the river; while they contemplated, with delight, the novel and diversified scenery of the high land before them. With such prospects, so favourable beyond all anticipation, it is not to be wondered if we indulged a rather sanguine hope that the continuance of health would be granted to us, and that we should, under Providence, thus be enabled to persevere in the great object of our mission. But it was otherwise ordained."—Page 73, 74.

"September 4.—Fever of a most malignant character broke out in the Albert, and almost simultaneously in the other vessels, and abated not until the whole expedition was completely paralyzed."—Page 74.

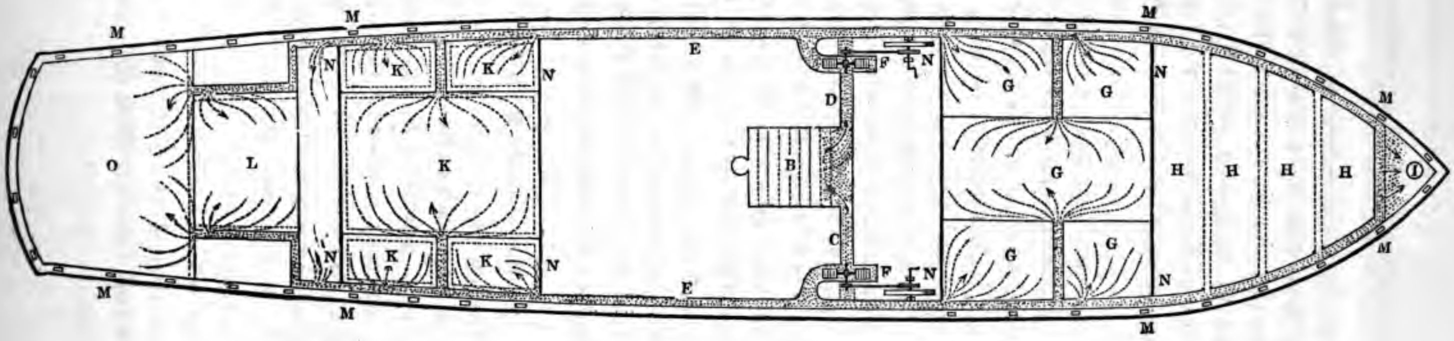
837. It may be proper for me to mention, that the fever attacked every one on board the Soudan, in which, from the nature of its construction, the medicator was of a smaller size, proportionally, than in the Albert and the Wilberforce; at the same time, it must be remembered that, as many sick were transferred to it from the other ships, I do not wish to attach so much importance to this observation as it might otherwise merit. Other circumstances also, well known to the officers of the expedition, prevented the atmosphere in the Soudan from being medicated to the same extent as that in the Albert and Wilberforce.

838. Dr Pritchett recommended the removal of the medicator, considering that, even if the chemical agents had been efficacious,

in their specific action on the malaria or miasm, they would have been required in larger quantity below deck, and to have acted also on deck, while he expresses an opinion that the African fever does not depend on the agency of any substance capable of being affected by the chemicals employed. This opinion I shall not attempt to controvert in the few observations I can devote to the subject of this chapter. I certainly take a different view of the question, which has been strongly confirmed by an observation made to me by some of the officers of the expedition, viz. that the stench from the wood on deck was often so insupportable that they often went below for the purpose of avoiding it. Experiments on myself have assured me, that, in extreme cases, it is the lesser evil to submit to a small supply of air free from certain poisonous ingredients, than to be accommodated with a larger quantity, though it contain only minute quantities of the noxious ingredient. In one experiment, I was for one hour and seventeen minutes in a box no longer than myself, no broader than my shoulders, and no deeper than my chest, all external atmosphere being hermetically excluded; and from what I observed then, many arguments appear to me to support the view of the medicator taken by Dr M'William, more especially on examining the results he has mentioned in the various elaborate reports he has made on the subject.

839. I embrace this opportunity of expressing my acknowledgments to Captain H. D. Trotter, in communication with whom I was placed by the African Society, and also to Captain William Allen, Captain Fishbourne, Dr Pritchett, and the officers of the expedition generally, for the assistance which I received in the application of my plans. To Dr M'William, with whom I was more particularly placed in communication, I have to express my obligations from the period when the ventilating arrangements were commenced, and particularly for the reports and observations which he continued, even in the midst of the arduous duties that engaged his attention, when the command of the Albert devolved upon him from the overwhelming sickness with which he was surrounded.

Fig. 299.



840. I have also to notice, that the progress made by Mr Laird with the materials for the iron ships of the Niger Expedition, having prevented them from being constructed in unison with the plans that would otherwise have been adopted, the ventilating arrangements had to be greatly modified in all their details. With the assistance of Mr Creuze of the Portsmouth Dockyard, the ventilation was arranged in the form which it ultimately assumed.

841. Fig. 268, page 368, gives a section which illustrates the action of the ventilating apparatus of the Niger steam-ships by the vacuum movement. Fig. 299 shews the operation of the plenum movement; B the purificator on deck, receiving air from the windsail attached to it; D C tubes conveying air from the purificator to the fanner, which was put in action by the apparatus (and worked by Kroomen, when the steam was not in operation, and the force of the stream not sufficient); H H H H H the forecastle; G G G G G midshipmen's section, illustrating the entrance of the air without diffusion; K K K K the gun-room and adjoining compartments, the air diffused, as it enters, by perforated zinc, bunting, or other porous materials; L O the captain's cabin; M M, &c., the gunwale tubes, through which the vitiated air was expelled in this case; N N N N the iron bulkheads, dividing the ship into five different compartments.

The following figures illustrate generally the mode of purifying and medicating air:—

Fig. 300. A the mouth of the windsail elevated as high as possible, or depressed according to circumstances; B the continuation of the windsail; C place for the deposition of impurities; D the filter; G chemicals for absorbing moisture; H I I I K shelves for chemicals and additional filters.

Fig. 301. An arrangement similar to Fig. 300, different materials being employed at G.

Figs. 302 and 303. Further illustrations of the mode of purifying air, by washing with lime-water or other substances, and filtering through various porous mixtures contained in dif-

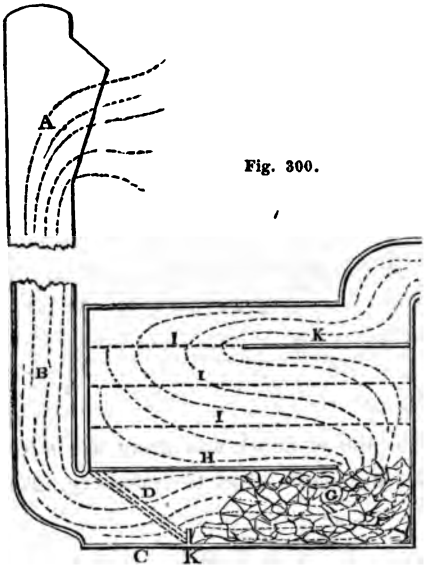


Fig. 300.

Fig. 301.

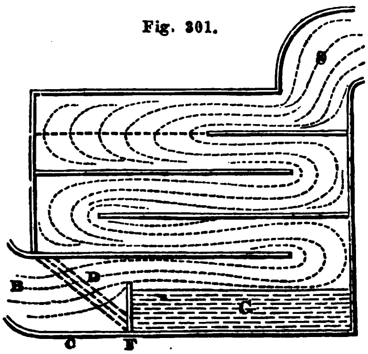
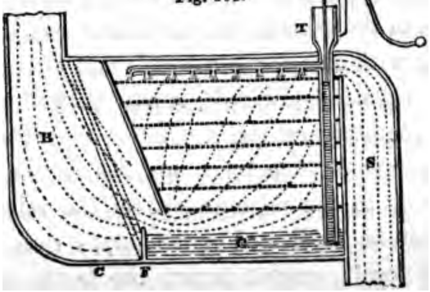


Fig. 302.



ferent compartments; S indicates the progress of the purified air from the medicator.

Fig. 303.

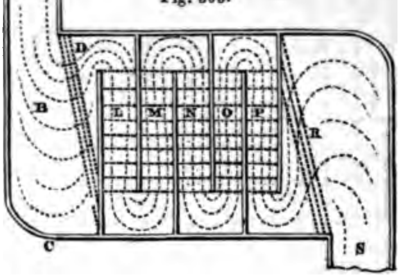
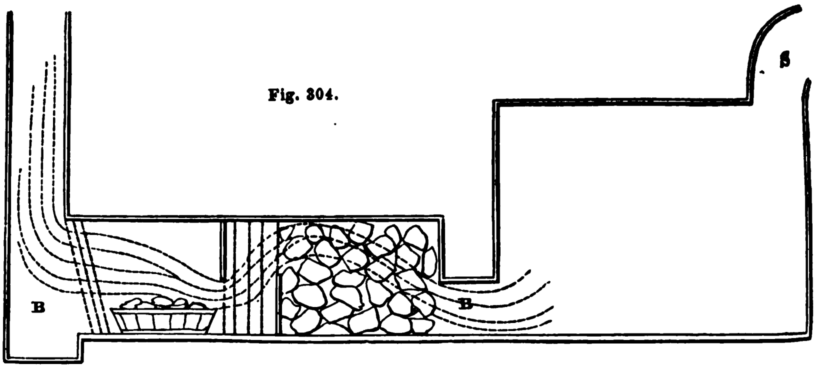


Fig. 304. B the windsail delivering air when the extreme action of powerful agents might be necessary, into a wooden box

Fig. 304.

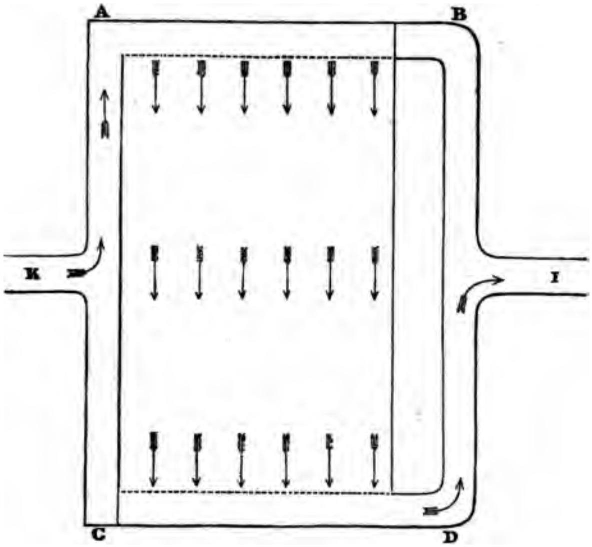


with two compartments, before it passed by B B to the medicator, these being applied in the first compartment, and any excess absorbed in the others; the medicator can be supplied at the same time with additional materials and filters.

Again, as a general principle, it may be well to remember, that, in each compartment the ventilating apparatus gave power to induce a movement from below upwards, or from above downwards, according to the arrangement of the valves, and that, whether the air be medicated or not, every care was taken to guard against local currents during the hours of sleep. If

the annexed figure (305) be considered as representing any cabin or section of the ships, then it is obvious that if K be an

Fig. 305.



aperture for the ingress of air, and I another for its discharge, by opening valves at A D, and shutting B C, a movement from above downwards will be induced as the arrows indicate. But if B and C be opened, and valves at A and D be shut, then the movement through the chamber will be from below upwards. Whether the air enter above or below, DIFFUSION ought always to be a principal object of attention; and though it may be impossible to adapt this to the extent represented, still it ought always to be introduced as extensively as circumstances permit.

DR M'WILLIAM'S REPORT.

ON THE VENTILATION.—" The power of the fanners to renovate the air in the compartments below, was abundantly proved during the passage from England to the coast.

By reducing the diameter of the drum, connected with the axis of the blade-wheel within the fanner, upwards of two hun-

dred and sixty revolutions could be performed in a minute, when the vessel was at full speed. Then a current of fresh atmospheric air was constantly being propelled below, capable, by proper adjustment of the valves, of having its power concentrated on one compartment, or even on one cabin of the ship. When we were at St Vincent, in the Cape de Verds Islands, the whole of the compartments were in succession cleared, and thoroughly cleaned. The process of drying the hold was much accelerated, by throwing the whole force of the plenum impulse exclusively into one division at a time. Under ordinary circumstances, the vacuum impulse, or exhaustion from below, was sufficient for the purpose of ventilation.

THE MEDICATOR OR PURIFYING CHAMBER.—In reporting upon the use of the medicator, I shall confine myself to the results of the experiments made on board H. M. Ship Albert, while in the Niger. These experiments were rather limited, from circumstances that could not be controlled; they were, in my opinion, however, quite sufficient to establish the medicator as a most useful, elegant, and economical medium, for submitting the external air to the action of chemical and other agents, whether with the view of absorbing carbonic acid and other deleterious substances from it as by lime; of chemically decomposing it under certain circumstances; of impregnation as by chlorine; or of altering its hygrometrical condition by substances capable of absorbing moisture from the atmosphere, or of imparting humidity to it.

The Albert entered the main branch of the Niger on the morning of the 12th August 1841, and anchored within the Bar for several days. It was not here considered necessary to open the lime-tanks, or to employ any other substance for the purification of the air, from the extreme fineness of the weather, the dry state of the atmosphere, the strong sea-breeze, the absence of any breeze from the shore, and the height of the river rendering emanations from its banks less likely. The number of revolutions obtained by disconnecting the paddles from the engines, and altering them to be turned by the action of the steam,

was sufficient to give from 48 to 70 turns of the fanner per minute. The valves were adapted to the vacuum impulse, until the afternoon of the 10th, when we ascended the river.

The medicator was now arranged as follows:—The windsails were hoisted, and attached to the lower lateral openings, which were covered with fine bunting. A filter of the same material was stretched across the upper tier, which is usually occupied by trays. Thus the air underwent filtration before it came in contact with the substances in the trays, and after it had been subjected to their action, chlorine was evolved from the lower compartment of the medicator, by disengaging it from the chloride of lime by means of sulphuric acid. On the second tier above this, about three hundred-weight of fresh lime (which was found in excellent condition) was placed. We anchored the first night at the top of Lewis' Creek, which is densely wooded all round. The mangrove abounds. The distance from the sea is about five miles. The sea-breeze was still felt.

The atmosphere between decks was not only impregnated with chlorine, but, as I shall have evidence to shew, it was felt to be drier, and proved to be so by actual hygrometrical observation.

Friday, Aug. 20.—Plenum impulse all day; chlorine evolved from the lower division of the medicator. The third tier was filled with fresh burnt lime, and above this, in the next range, about ten pounds of the chloride of calcium. Anchored near a small village; we were about 150 yards from the banks on each side, which were densely wooded.

August 20. 11 P.M.	Thermometer.	Dry Bulb.	Wet Bulb.	Difference.
On the Upper-Deck, . . .	78°.0	77°.5	75°.0	2°.5
In the Captain's Cabin, . .	83.0	83.0	79.5	3.5
Gun-Room, ...	82.0	82.0	78.0	4.0
Lower-Deck, ...	84.5	84.5	81.0	3.5
August 21. 1 A.M.				
On the Upper-Deck, ...	77°.0	77°.0	75°.0	2°.0
In the Captain's Cabin, . .	80.5	80.0	76.4	3.6
Gun-Room, ...	80.5	80.0	76.4	3.6
Lower-Deck, ...	82.0	82.0	78.5	3.5

Aug. 21.—Plenum movement, with evolution of chlorine during the day. In the evening, anchored below (to avoid a swamp) a village on right bank, called "Keambli."

SUNDAY, AUG. 22. 2 A.M.	Thermometer.	Dry Bulb.	Wet Bulb.	Difference.
On Upper-Deck, ...	78°.0	78°.0	76°.0	2°
Captain's Cabin (no lights), .	81.5	81.0	77.0	4
Gun-Room do. .	81.5	81.5	78.0	3.5
Mid.'s Berth do. .	83.0	83.0	79.5	3.5

Monday, Aug. 23.—Evolution of chlorine in minute quantity; chloride of calcium and dry lime on the trays. Anchored at 9 P.M. in the middle of the river, about 200 yards distant from the banks. Results as before.

Aug. 24.—The same.

Aug. 25.—Chlorine evolved; dry lime in medicator; chloride of calcium being liquefied was removed.

AUGUST 25. 9 A.M.	Thermometer.	Dry Bulb.	Wet Bulb.	Difference.
On Upper-Deck, ...	78°.5	78°.0	76°.0	2°.0
Captain's Cabin, ...	79.0	79.0	76.0	3.0
Lower-Deck, ...	84.0	84.0	81.0	3.0
Gun-Rooms, ...	81.0	81.0	77.5	3.5

At 12.30 P.M. the filters at the lower lateral openings were removed, and found covered with dust, which, examined through the microscope, was found to consist of small vegetable fibres, particles of black matter, fibres from cloth, portions of grass, woody fibre, &c.

3 P.M.—During a heavy shower of rain, when off the village Imbillamma, the hygrometer indicated as follows. The cabin and gun-room were, at the period of the experiment, nearly wholly supplied with air, which had passed through the medicator, the port-windows being shut to exclude the rain.

AUGUST 25. Revolutions of Fanner with Steam, 56.	Thermometer.	Dry Bulb.	Wet Bulb.	Difference.
On the Upper-Deck, . . .	78°.0	78°.0	76°.0	2°.0
Captain's Cabin, ...	82.5	82.0	78.0	4.0
Gun-Room, ...	82.0	82.0	78.0	4.0
STIRLING ISLAND. 9 P.M.				
On the Upper-Deck, . . .	78°.0	78°.0	76°.0	2°.0
Captain's Cabin, ...	82.5	82.5	78.0	3.5
Gun-Room, ...	82.5	82.5	78.0	3.5

On our arrival at Aboh, on the 26th, the same mode was adopted, and the effects were fully as clear as in the former experiments. The fanner was kept going night and day, until we reached Egga, when the engineers being all sick, we had no one to disconnect them from the engine. On our return down the river, and from thence to Fernando Po and Ascension, the exhausting impulse was put on; it was sufficient when the ship was out of the river.

As regards the supply of medicated air between decks, I should say that it is sufficient for respiration in the captain's cabin, and gun-room, when there are comparatively few individuals. On the lower deck, however, where, in proportion to the space, there are so many people at night, constantly rendering the air there unfit for the purpose of respiration, the quantity of medicated air, transmitted through the tubes, was inadequate to the demand. The closure of the hatches of the lower deck could not, therefore, be tolerated; in fact, the heat was so oppressive at Egga, that we were obliged to allow some of the men to sleep on deck.

The air on the lower deck, from the cause above mentioned, always contained a proportion of the common atmosphere, which may or may not have been prejudicial. At all events, we have every right to presume, from the acknowledged powers and properties of the chemical agents used, that an atmosphere, if

vitiated, cannot fail to be materially improved by any admixture of air which has been subjected to their action.

(Signed) J. O. M'WILLIAM, M.D.
Senior Surgeon, Niger Expedition.

H.M.S. ALBERT, ASCENSION,
April 1842."

Extract from letter of Captain William Allen, of H.M.S. Wilberforce, dated Teneriffe, 28th May 1841 :—

"We have made the second stage of our voyage as prosperously as the first.

"The ventilation answers very well. While all the men were in their hammocks, and the night very warm, I found the air perfectly pure and cool. I have no doubt but that some important results will be obtained from the experiments we are making, and I hope that the system will be generally adopted. I would give you details of the experiments, but they have not hitherto been so full as I wish, and I believe Dr M'William has given you his observations."

CHAPTER IV.

SLAVE-SHIPS.

842. The following figures shew the position of slaves in the more crowded slave-ships. The accompanying extracts are from Sir Powell Buxton's Report :—

Fig. 307.

843. It might be expedient for vessels sent to capture slavers to be provided with a portable ventilator, which might prove useful in removing the atmosphere before the sailors enter below deck, when it is in an extreme condition, and also when they may have to be conveyed for a considerable distance before they reach the shore.

" In these ships the negroes are stowed between the decks, which are seldom more than two or three feet, and sometimes not more than eighteen inches in height.

" In this condition, men, women, and children, perfectly naked, and, in many cases, the women either in a state of pregnancy or carrying their children of from four to twelve months old, are conveyed to their wretched holds. In these dungeons of misery, they are packed together so close, that, in some in-

stances, they are obliged to lie on their sides, and, from the small space between the decks, are unable even to sit erect.

Fig. 207.

Fig. 208.

"The most vivid idea of this particular may be gathered from the manner in which those who have witnessed the scene describe it. They tell us, that the negroes are packed so close, that it is impossible to move without treading upon them; that in one case, one hundred and thirty-two occupied a space in which there was not room for more than thirty at full length; that they are stowed literally in bulk; that they are packed like bales of goods; that they are packed like herrings in a barrel. The sufferings arising from this source it is impossible to describe, nor can the mortality it occasions be computed.

"Nor is this all. The misery originated by these circumstances is fearfully aggravated by the small quantity of air which can possibly get to the negro-rooms. Most of the ships are in-

deed provided with air-ports. But if the sea is rough, or the rains heavy, these, and every other avenue by which air is admitted, must be closed; and the fresh air being excluded, the slave-holds become intolerably hot, and a dreadful amount of wretchedness ensues.

"By these combined causes, numerous diseases are engendered. The confined air, rendered noxious by the effluviæ exhaled from the bodies of these unhappy beings, being repeatedly breathed, soon produces fevers and fluxes, which carry off great numbers. Sometimes two-thirds perish. In one instance, fifty-five were carried off in seventeen days; and, in another case, out of a cargo of seven hundred, three hundred and fifty were lost before they reached the place of their destination. The smallpox often breaks out, and is fatal to multitudes. Six hundred, in one vessel, have been destroyed by it; and, on another occasion, a ship which left the shores of Africa with four hundred and thirty-eight slaves, reached its destined port with only seventy. They fell by this disease. The measles sometimes makes a fearful havoc amongst the unfortunate negroes. One case is recorded in which two hundred and fifty-three were victims to it.

"The hold of a slave-ship presents a spectacle of disgusting wretchedness and piteous woe, which cannot be equalled, and completely beggars description. It is often filled with masses of living corruption, and you may sometimes see women in all the pangs and throes of labour bringing forth children, with men dying at their side, and not unfrequently living men chained to those who are dead, the latter often being in a putrid state. Such is the stench which these circumstances of horror combine to produce, that it is hardly possible to bear it for a single moment. Well did Wilberforce observe,—'That never can so much misery be found condensed into so small a space, as in a slave-ship during the middle passage.'

"But this is not all. The water and provisions of the slaves are kept under them. With the latter they are most scantily supplied, and from the want of the former, they suffer more than from almost any other source. Such, indeed, are their suffer-

ings from thirst, that, in one instance, Dr Walsh narrates a vessel being captured, and the slaves being brought on deck, and water being presented to them, they all rushed like maniacs towards it. No entreaties, or threats, or blows, could restrain them. They shrieked, and struggled, and fought with one another for a drop of the precious liquid, as if they grew rabid at the sight of it.

"The negroes, in a state of desperation, not unfrequently destroy themselves. When they are brought on deck for fresh air, knowing that they are doomed to return to the place of their former miseries, they often, locked in each other's arms, leap into the sea, and seek, in the embrace of death, the termination of their woes. So customary is this, that slave-ships are generally secured by netting all round the decks. But the suicides bear no comparison, in point of numbers, with the murders. It is computed that no fewer than three thousand slaves are annually thrown overboard. If the captain of the vessel apprehends that his supply of water will not hold out till the end of the voyage, he meets his difficulty by devoting to the waves the surplus of his wretched cargo of human beings, retaining only those for whom he calculates that he has a sufficiency. On one occasion, on this account, one hundred and thirty-two were destroyed."

PART VII.

BRIEF REMARKS ON THE VENTILATION OF MINES.

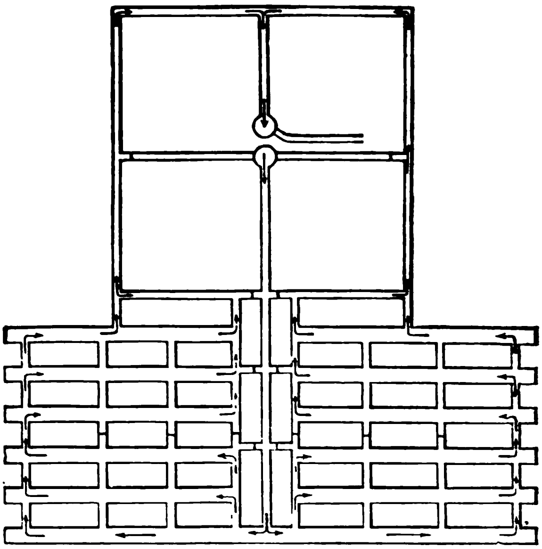
---

844. In the mines which I have visited, the same great and leading defect was generally observed, that is usually noticed in public buildings and private dwelling-houses, viz. a deficiency in the quantity of air supplied. In mines, however, the great comparative difficulties that are presented in obtaining the necessary channels for the ingress and egress of air, necessarily present more extreme cases of deterioration in the quality of the air, than are usually met with in ordinary buildings. Till this primary evil be rectified, in respect to the amount of supply, no satisfactory results can be anticipated, although the principles may be accurate on which the ventilation is founded. Different mines have been named to me, in which the amount of supply was said to have been very great, but in none that I have as yet visited was the ventilation maintained so powerfully in action as it is daily at the House of Commons in sultry and oppressive weather. Improved lamps may enable the miner to penetrate into a dangerous atmosphere with less risk of accident; but this is never continued for any length of time, without permanent injury to the health from the continued respiration of vitiated air; and it may challenge investigation whether the injury arising from this source has not greatly exceeded the bad effects that have arisen from

explosions in coal-mines, and all other accidents whatsoever, as its slow and gradual operation insidiously undermines the constitution, and abridges the term of human life, though its influence has not drawn that marked attention to its operation, which its ultimate effects demand.

845. A sufficient amount of supply having been secured by the operation of a draught determined by heat, by steam, by machinery, or by the conjoined use of any or all of the agents used for ordinary ventilation, as local circumstances may indicate; the next point that requires attention is the distribution of the air, so as to render the amount supplied as effective in its operation as possible. The accompanying fig. 309, illustrates the arrange-

Fig. 309.

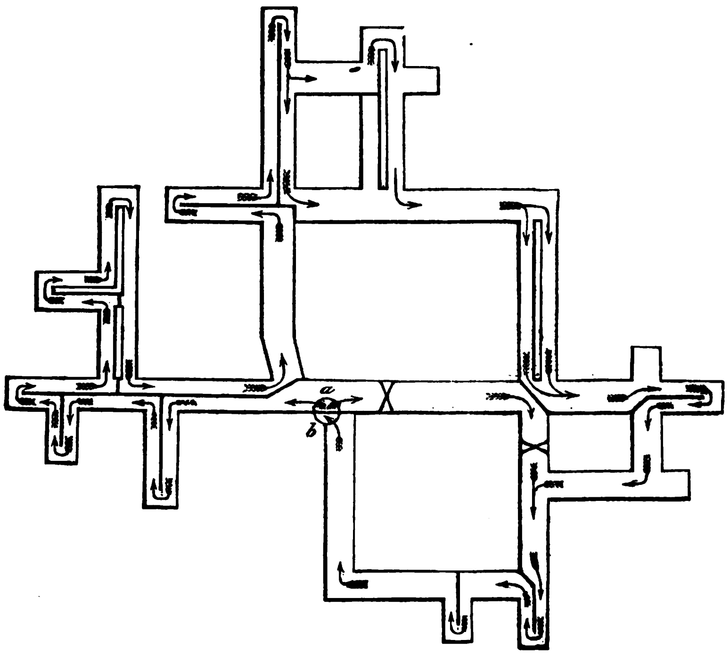


ments adopted in coal-mines, one of the circles indicating a shaft which supplies the mines, the air proceeding through the mine as the arrows explain, and passing ultimately to the second shaft, from which it escapes into the external atmosphere. The first -haft is termed the DOWNCAST SHAFT, as air proceeds downwards 'gh it to the workings of the mine. The second shaft is

called the UPCAST SHAFT, as the vitiated air ascends through it to the open air; and it is in it that the column of warm air is usually produced, on which the ventilation of the mine depends, a large fire being sustained below for this purpose, at a little distance from the bottom of the shaft.

846. In many pits, instead of two or more shafts, one only is used, a division or partition in the centre, allowing one-half to be used as a downcast shaft, and the other half as an upcast shaft. The annexed fig. 310, shows a plan of ventilation of a

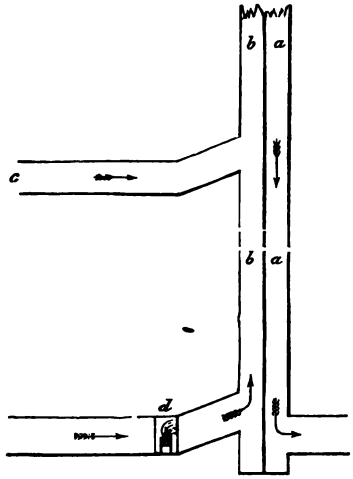
Fig. 310.



mine having only one shaft, the air supplying the mine descending by *a*, and the vitiated air escaping by *b*. The descending air at *a* may be directed solely through the workings of the mine, or part of it may, at times, be sent through the great communicating passage on the right, by leaving small apertures in the doors. Fig. 311, is a section shewing the descending and

ascending divisions of the shaft, the fire-place *d*, and a branch air-drain *c*, communicating with the upcast or ascending half of

Fig. 311.



the shaft. It is scarcely necessary to remark, that unless the partition be made and preserved air-tight, and the discharged air be separated carefully from that which enters, part of the vitiated air in the upcast shaft must always be returning into the downcast shaft, and excluding a portion of fresh air, which would otherwise enter.

847. Communications with the upcast shaft, such as *e*, are not made solely with the view of carrying off vitiated air from any superior level where mining operations may be carried on, but also with the view of discharging even from the lower level, inflammable products not sufficiently diluted with air, and, therefore, too dangerous to admit of their being conveyed across the furnace below, from their liability to take fire and explode. By allowing them to enter the upcast shaft at a greater or less altitude above the fire, as may be necessary, the risk of explosion n this source is greatly diminished, or entirely averted. The assage *c*, is usually termed a dumb passage or shaft.

e miner does not work in general in the great air-

course, but rather in excavations connected with it, where a secondary current, branching off from the leading channels, supplies him, merging again with increased impurities into the general current. Hence, the air which he breathes may be much worse than the average quality of that which passes through the mine.

849. Again, in some mines, the air travels ten, twenty, thirty, or even a greater number of miles, in traversing the whole mine, so that it is impossible to prevent the last portions of the mine receiving air largely contaminated with offensive products added to it in its progress. SHORTER AIR COURSES, therefore, which have been strongly recommended of late, form indispensable requisites in many mines where the air is of inferior quality. Were there a central up-cast shaft for the discharge of vitiated air, and fresh air supplied from leading air-courses surrounding the workings of the mine, the great ventilating channels passing from these (which might be represented by the circumference of a wheel) to this central discharge, by direct branches radiating to a common centre (like the spokes of the wheel), then the pure air given would act much more equally. The first part of the air-courses would not be subjected to such a powerful current of air from the down-cast shaft, and the last portions would be contaminated solely with the air from their own district, instead of being as foul as that in the up-cast shaft. Such a mode should be approximated in practice, as far as circumstances permit, or the long air-course should be broken into shorter air-courses, each being provided with its down-cast and up-cast shaft. Endless varieties of arrangements occur in practice, and may be adapted to the peculiar circumstances of each individual mine.

850. In all large mines, numerous doors are placed to enable men and materials to pass from one part of the mine to another, without being compelled to follow the circuitous air-courses though which the air is directed. Should any of these doors not be carefully shut by the boys attending in the mine for this purpose, the whole system of ventilation may be rendered useless; the air may take the shorter course through the cross passages,

in the same manner as the men, and large portions may be left in complete stagnation, the fire damp accumulating in some cases till an explosive mixture is formed, which fires when it comes in contact with the flame of the furnace, when the general ventilation is restored by shutting the doors of the communicating passages.

851. The precise analysis of air in different parts of mines, from time to time, so as to ascertain the quantity of carbonic acid in the atmosphere respired by the miner, and of any other local impurity, such as the nature of each mine may render it liable to, appears to be one of the most important objects to which those entrusted with their management can direct their attention. The long time that the common candle continues to burn in many places in mines where the workmen are occupied, is a familiar fact, which proclaims in language not to be misunderstood, the inferior quality of the air which he breathes. Accordingly, were nothing further done, the amount of carbonic acid ought always to be reported daily, wherever the ventilation is not on a proper system either as to quantity or quality, and still more in coal-mines and other places where the miner is subject occasionally to emanations of this gas from the strata in which he works, or from slow combustion, and beyond what he is subjected to from his own respiration and from the combustion of lamps and candles. The carbonometer, explained in Part I., might be employed advantageously, at all times, in the upcast shaft of coal mines, making allowance for the products added by the ventilating fire; or it might be placed below in the mine to the windward of the fire, so that its indications should not be complicated with the products of combustion from this source. But though this would be an important step in giving information as to the general state of the atmosphere of the mine, it ought also to be accompanied, from time to time, with local examinations of the actual state of the air at the spot where the miner works, otherwise it can never be considered satisfactory. Means also should be adopted, in extreme cases, for obstructing occasionally, for a short period, the usual progress of the leading air course, as it passes some

very noxious secondary air-course or side branch, on which it may exert only a trifling influence, and for permitting it to be directed fully through it, so as to renew entirely the air that may have been stagnating in it. This would prove no interruption to the general progress of the ventilation, and, if continued only for a minute, would still be accompanied, in many cases, with the most beneficial results.

852. It will be noticed, that all the resources of ventilation may be applied to mines, as they are ventilated on the same principles as other places. Machinery and heat, by fire and by steam, have all engaged attention as moving powers for determining a current of air. In coal-pits, where the greatest proportional amount of ventilation is usually required, large furnaces have long been in use for determining an ascending current of air, fresh air entering to supply the place of the vitiated air which is discharged.

853. In general, salt-mines present the coolest and most agreeable atmosphere; but in coal-mines the air is most frequently observed in a state of great impurity. Some of the salt-mines at Northwich, in Cheshire, for example, present large and capacious galleries; the floor is covered with powdered salt, which looks like sea-sand, and high roofs are supported by pillars about eighteen feet square. Neither the material, nor the mode of working, communicates so large an amount of impurities to the air as in coal-mines, where carbureted hydrogen, carbonic acid, and the products of respiration from great numbers of horses as well as men, and the more extensive use of gunpowder, all contribute to deteriorate the air. These causes tend to render the effective ventilation of coal-mines more important and imperative than that of most other mines, the accidents that arise from them being much more disastrous in general than those that take place in other places.

854. In coal mines the amount of ventilation demanded is exceedingly various, according to the extent of the pit, the mode in which the workings are carried on, and the nature of the coal. In such mines enormous reservoirs of condensed inflammable gas

are occasionally tapped, when their contents are discharged with extreme rapidity, producing an atmosphere so dangerous, that no security can be expected in the mine, if safety lamps are not in use. In some cases the gas is speedily discharged; in others it continues to burn for years, when a communication is made between the magazine and the external air by an iron pipe, through which the gas is conveyed to the external air before it is inflamed. Such streams of inflammable gas are usually called *Blowers.*

855. While all pits are subject to the influence of vitiated air arising from respiration, and from the combustion of lamps and candles, some coal-pits are so largely charged with carburetted hydrogen, that unless it be removed, and diluted by a large quantity of air as it escapes, dangerous explosions ensue, and these have sometimes been accompanied by the deaths of upwards of a hundred persons. In such cases, the miners, if not scorched and killed by the explosion, are often suffocated by the products of combustion, which return upon them when the force of the explosion has passed away.

856. The introduction of Sir Humphrey Davy's lamp, and his brilliant discoveries on the nature and properties of flame, constituted a new era in the history of coal mines, from the extent to which it has led the miner into fields of coal that would have otherwise been inaccessible. The value of the discovery has been greatly lessened in a practical point of view by the comparative omission of that more extended ventilation, which, unfortunately, did not accompany its introduction, and which was imperiously demanded by the more impure atmosphere in which the miner too often entered, losing sight too much of the influence of the air he respired upon his general health. It is not meant that ventilation was entirely neglected; on the contrary, this difficult and complex question has received a daily increasing attention from practical miners, and men engaged exclusively in scientific pursuits. But it is obvious that, amidst the interest and enthusiasm justly accompanying the introduc- the safety-lamp, a proportionate amount of attention was n to those means of sustaining freedom from danger by

a more perfect ventilation, and consequent dilution of offensive and explosive atmospheres, which must always form the great aim and object of those to whom the health and safety of the miner is entrusted. The miner should not be called upon to work in an atmosphere in which the amount of impurity exceeds some fixed and definite standard; the Davy lamp should not be used to enable the miner to be placed in situations where, though protected from momentary danger, he is necessarily enveloped in air whose extremely inferior quality undermines his health. Its legitimate use is to guard him against the risk of accident, and not to allow him to be placed under circumstances against which no constitution can be expected long to strive.

I have been led to make these observations from the conviction which has been daily strengthened for many years past, that the evils of the present ineffective supplies of air in many mines are not fully appreciated, and that any inquiry into the health, strength, and length of life of a large number of miners who work in ill ventilated coal-pits, will bear out the view which I have expressed. With respect to the Davy lamp itself, which I have tried in every situation in the most explosive mines, I may state that I concur with those who consider that it should be materially altered. Placed in a current, especially when the miner is proceeding in an opposite direction, I have seen it again and again blown out; and the force with which the flame may be directed upon the side, or a spark carried through the meshes, especially if any coal-dust shall have rested on them, may be considered justly as very possible causes of occasional explosion. On the whole, I may add, that the last modification of the lamp introduced by Dr Clanny, who had the merit of constructing a lamp with which the miners entered safely into explosive atmospheres, before any other person in this country had directed any attention to this question, and in which he has availed himself of the use of the wire-gauze introduced by Davy, is the most important I have hitherto seen. Dr Clanny preserves the flame upright at all times by a strong cylinder of glass, which enables the flame to give more light than what can be obtained from the safety-

lamp; it is defended by a guard, and I have plunged it in water without fracture, after using it for an hour in one of the deepest mines in this country; it was not blown out nor affected by a current that rendered the Davy lamp comparatively useless as a source of light; the wire-gauze above gave it ample protection from fire-damp, and caused, from the mode in which the fresh air descends, and the vitiated air escapes, a very singular and interesting series of currents within the lamp itself, well worthy of the most minute and serious investigation as a question of general interest, independent of their local bearings on this particular lamp. I must add, however, that I concur with those who consider that the glass cylinder should be replaced by a double cylinder of mica, the interior being placed one-eighth to one-fourth of an inch within the outer cylinder. In the Mueseler lamp, which has been strongly recommended in Belgium, the principle is introduced which forms one of the principal peculiarities in Dr Clanny's improved lamp, the air that supports the combustion of the flame descending to it, instead of rising upwards in the usual manner.

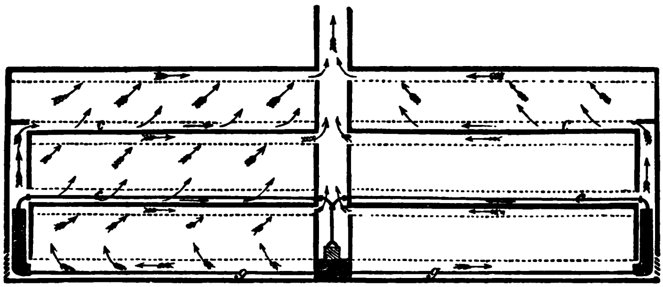
857. The necessity of preparing and preserving proper maps and records of the workings of mines has recently received much more attention than formerly, though still far below that which the necessities of the case demand. Mr Sopwith's earnest and untiring zeal in the recommendation of this question to public consideration, cannot fail to assist greatly in forwarding this important cause, so essential to the proper and economical management of mines, and to the application of the best means for effective ventilation, independently of the security it presents against accidents.

The reader who is more especially interested in local mines is referred to the report of the Committee of the House of Commons on accidents in Mines, and to a subsequent report of the South Shields' Committee on the same subject, with which Mr Mather's name is more particularly associated, whose important and comprehensive view of the question, and very valuable suggestions, deserve the highest consideration.

APPENDIX.

Fig. 312 gives a connected view of the ingress and egress of air, such as has formed the basis of arrangement in many public buildings, where the infusion of a mild and equal atmosphere into

Fig. 312.

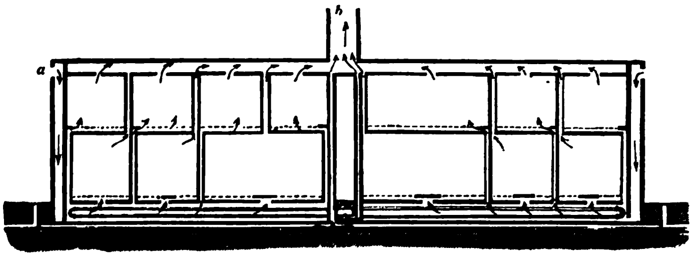


halls, corridors, and lobbies, gave the supply required for individual apartments. A central boiler gives heat to the water in the pipes connected with it to the apparatus in which it is expanded—and to the pipes returning the water to the boiler. The fresh air enters below at either end. In each floor, the warm fresh air enters below, the vitiated air escapes above into a central shaft.

Fig. 313 shews the same system applied directly to individual

apartments, the fresh air being taken, not from corridors and passages, but from a common chamber below. In this case, the

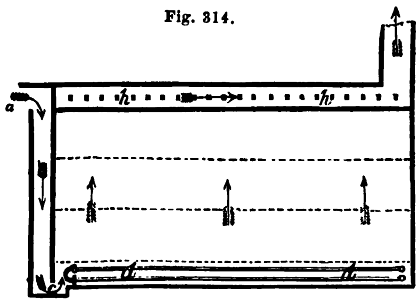
Fig. 313.



fresh air descends from a higher altitude to the chamber of supply, a course which is constantly resorted to where vitiated air predominates at the surface of the ground. A central boiler supplies warm-water pipes placed in the basement. Air from drains escapes directly into the vitiated air-shaft above.

Fig. 314 represents a similar arrangement, and the termina-

Fig. 314.



tion of individual flues, *h h*, in a common viated air-chamber in the roof.

Fig. 315 shews the mode of connecting a descending shaft with the flue in the roof, where sufficient altitude cannot be obtained there for determining the velocity required in the dis-
harging current. In all cases where flues are combined in the
r represented in any of the four preceding figures, the

air-channels both for the ingress and egress of air should be ample, otherwise they cannot be used freely.

Fig. 315.

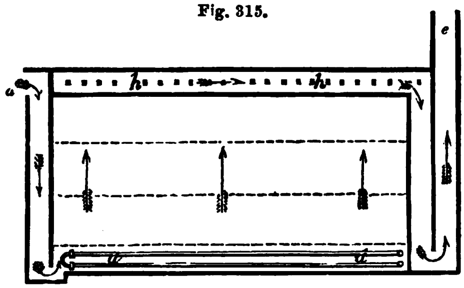
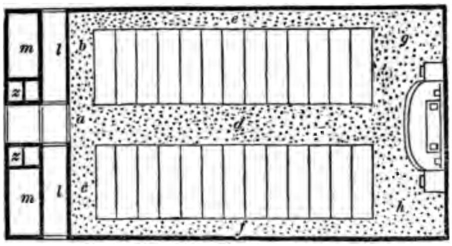


Fig. 316 shews where the dotted ground appears, *a b c d e f g h*,

Fig. 316.



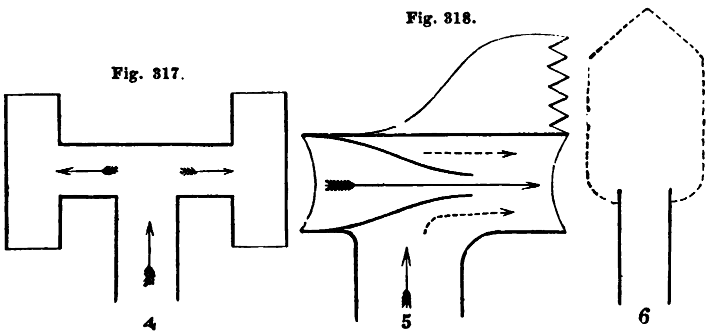
the amount of diffusion which can be given in many churches, where the aisles are not occupied by free seats; *m m* vestry and heating rooms; *l l* passages; *z z* fresh air shafts.

Figs. 317, 318, 319, 320, and 321, represent some of the

Fig. 317.

Fig. 318.

Fig. 319.



4 5 6

endless varieties of forms that have been long used to prevent

the influences of the external air from producing down-draughts in chimneys. It is scarcely necessary to remark, that, however important it may be to protect chimneys from the wind or local eddies, all such arrangements tend to obstruct the natural discharge of the vitiated air in calm weather, and that no external arrangement can prevent smoke, unless worked by power, mechanical or calorific, where there is a defective supply of air within to support the current in the chimney. The blow-pipe cowl (318) is very useful, where there is equal and continued wind;

Fig. 320.

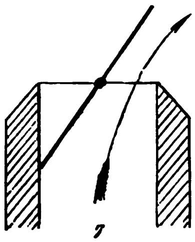
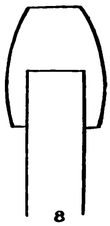


Fig. 321.



but in the last case referred to, the atmosphere being calm, it would rather retard than accelerate the discharge of air from within. In the same manner, all machinery placed in a chimney or air-flue, if not worked by power so as to command greater velocity than that with which the current ascends, retards, and opposes, instead of promoting the discharge.

Note on Grave-yards. (Text, p. 52.)

Deaths have, indeed, occurred occasionally in some church-yards from this cause; and in a series of experiments made in one of the grave-yards of Manchester, where deep graves are made, each capable of receiving from twenty to thirty bodies, I found in general, that a grave covered with boards at *night*, was more or less loaded with carbonic acid in the morn-

ing, and that it was essential, accordingly, to ventilate these grave-pits, before it was safe to descend. This was effected, on some occasions, by means of a small chauffer placed at the top and at one end of the graves, a tube or hose being led down from it to the bottom of the grave. The fire was sustained by the admission of a small portion of fresh air at the top, and the air from the bottom of the grave was gradually removed as the upper stratum was heated by the fire around which it was conveyed; and when it had been once emptied in this manner, a small fire was found sufficient to sustain a perpetual renewal of air, and prevent the men at work in the grave-pits from being subject to the extreme oppression to which they are otherwise liable, even when there may be no immediate danger. A mechanical power might be used for the same purpose, and chemical agents, as a quantity of newly slaked lime, are frequently employed as they absorb the carbonic acid. From different circumstances that have since occurred, it appears to me probable that numerous examples of strata or superficial soil, containing carbonic acid, may be more frequently met with than is generally suspected, and that, while in graveyards the presence of large quantities of carbonic acid may often be anticipated, its presence must not always be attributed solely to the result of the decomposition of the human body. From whatever source, however, the carbonic acid may arise, it is not the less prone to mingle with the surrounding air; and where the level of the floor of the church is below the level of the churchyard, there the carbonic acid is prone to accumulate, as, though it may be ultimately dispersed by diffusion, it may be considered as flowing in the same manner, in the first instance, as water, where the quantity is considerable.

Note on Cleansing, Drainage, and Sewerage.
(Text, p. 56.)

a. Animal and vegetable matter, in a state of putrefaction, tends to produce disease, and is the cause of many of the most malignant maladies to which humanity is subject.

b. Even where the effects it produces are not marked, it is often the cause of a low tone of health, and leaves the system incapable of contending with evils which it might otherwise overcome.

c. The immunity which some individuals have from evils produced by such causes, is no argument against their general influence. A well fed constitution, and a peculiar diathesis, may resist evils that lay numbers prostrate, and act with extreme severity on temperaments reduced by want, anxiety, fatigue, or other depressing circumstances, or exposed, in peculiar states of the atmosphere, to the causes of disease. Besides, there is no proof that powerful constitutions, whose vigour may protect them from the inroads of severe disease, are not deteriorated below the standard of health they would otherwise present, under circumstances that affect severely their less fortunate neighbours.

d. All accumulations of decayed animal and vegetable matter which it may be impossible to prevent, should be isolated from dwelling-rooms, workshops, and other places in frequent or constant occupation, or they should be constructed so as to be controlled by ventilating arrangements that cause them to draw in air from other places, and not discharge their offensive atmosphere, where it may enter into any ordinary apartments.

e. A special flue, with a fire-place arranged so as to control effluviæ from such sources, is essential, in many cases, to prevent offensive emanations, and to insure their decomposition, as they are subjected to heat in passing the fire.

f. Even where no heat is employed to decompose such ema-
tions, the constant action of a current of air diminishes and
their virulence.

g. Air from open sewers should be avoided, presenting a constant source of deleterious exhalations, the less the flow of water, and the less the degree of dilution.

h. In the same manner, if the air from open sewers be offensive, still more is the air from covered sewers liable to objection, the absence of light and fresh air preventing decompositions, which tend powerfully to purify the air.

i. In the construction of sewers, accordingly, it is important to provide means of ventilation, not only with the view of oxidating many of the noxious products developed there, the free action of the air tending ultimately, by its chemical influence, to purify and sustain, in a less fetid condition, the sides of the sewer, but also to dilute, to a great extent, the products that are evolved, and render them comparatively inoffensive.

k. The more perfect the sewerage and drainage, the less the contamination from the air they evolve. The air from a sewer, however, must always be so far contaminated as to be offensive, even when the supply of water is considerable. Hence then, it should not be left to escape promiscuously at gully-holes, in the streets, but, whenever it is practicable, be discharged into the atmosphere, like other offensive products, by a shaft placed at the highest accessible point.

l. When drainage and sewerage are imperfect, the gaseous products then liberated are necessarily the most offensive. It cannot be too particularly remembered, that it is the gaseous emanations from drains and sewers which are the true vehicles of disease; and any power, accordingly, that can control and destroy such emanations, effects a powerful sanitory improvement, calculated to afford great relief till effectual measures for better drainage and sewerage can be adopted.

m. The ventilation of drains is a subject of great practical importance, and the key, as to the mode of management, will at once be understood, if the essential point be remembered that a power must be arranged so that *instead of vitiated air passing from the drains or sewer to the adjacent premises, fresh air shall proceed from them to the sewer*, aerating it freely, and then

carrying any impurities it may gain in its progress to the shaft, where it may be diluted or consumed.

n. All dust-bins, sculleries, and similar places, should be treated in the same manner.

o. When the barometer falls, offensive emantions from sewers may be perceived in almost all crowded cities and populous districts. In London, one may walk, from Maida-Hill to Lambeth, or from Kingston to Blackwall, and on examining any opening connected with a drain, the discharge of vitiated atmosphere will generally be perceived.

p. The addition of lime-water, chloride of lime, or other chemicals adapted to peculiar circumstances, has a very purifying influence on the water of drains and sewers, and acts equally on ground contaminated by emanations from them.

q. Where drains are not ventilated, the air in them generally becomes so bad, that it often proves fatal to enter them, if a circulation of air be not previously induced.

r. Drains are protected by traps or valves from discharging noxious air into apartments communicating with them. The bell-trap, and the bricklayer's-trap are the most common arrangements used for this purpose, the former being usually applied in sinks where a small flow of water is expected, and the other in large drains and sewers. All circulation of air is arrested where they are in use.

Special Illustrations of the Influence of the Air of Drains on Houses. (Text, p. 56.)

1. In a house in —— Street, (London) the air in the ground-floor is so largely contaminated with noxious emanations from drains, that meat there usually becomes tainted in one day, in warm weather, while, in the upper apartments of the same house, two to three days elapse before a similar effect is pro-

2. The case recorded in page 335 gives an illustration, where, for a long period, the whole basement of an hospital was flooded with impurities from the drains.

3. In the ——— Court, having been dissatisfied with the condition of the air, after considerable arrangements had been made to improve it, the whole floor was at last taken up, and it was soon discovered that a drain which passed under the benches near the judges' seat, had been cut through with the view of obtaining a passage for a hot-air copper pipe, and left perfectly open, excepting the trifling amount of area closed by this pipe. This, at once, explained the cause of endless complaints which had never been intermitted, for a single session, during the preceding fifteen years.

4. In another court, the whole products of waste cabbage-water, &c. &c., from the public kitchen, evaporated from a cess-pool under it, which had not been cleaned for twenty years. When the cess-pool was examined, I found that it had no communication whatever with any external discharge, and that during the long period mentioned, there was abundant evidence to prove that all the liquid products it received had no escape, except by evaporation into the atmosphere that supplied the courts above.

5. In the ——— Barracks, in consequence of the non-ventilation of a drain, the men were exposed to an intolerable current of air from it, fertile in the production of disease.

6. In the ——— Barracks, meat could not, in general, be kept fresh a single day, during summer, and all wounds were prone to assume an erysipelatous character, in consequence of the emanations from drains, and materials in a state of decomposition in the vicinity.

7. In many of the larger mansions, nothing is so commonly observed as the vitiated air from drains, kitchens, sculleries, and dust-bins, finding its way to the basement, and from there to the whole of the house.

Extract from Dr Reid's Explanations on Smoke, printed in the Report of the Committee of the House of Commons on Smoke.

"The term smoke, applied in common language to any 'sooty exhalation' or 'steam,' includes a great number of products, ever varying according to the nature of the materials from which it proceeds, and the manner in which they are subjected to the action of heat and air, or other materials.

"I. Black smoke consists essentially of carbon, separated by heat from coal or other substances.

"1. If this smoke shall have been produced at a very high temperature, the carbon forms a very loose and powdery soot, comparatively free from other matters.

"2. The lower the temperature at which black soot is formed, the larger the amount of other substances with which it is mingled, among which, the following may be more particularly noticed:—Carbon—water—resin—oily and other inflammable products of various volatilities—ammonia—carbonate of ammonia.

"3. When the carbon, oils, resin, and water, are associated together in certain proportions, they constitute tar. Soft pitch is produced, if the tar be so far heated that the water is expelled, and hard pitch, *i.e.*, resin blackened by the carbon, when the oils are volatilised. A further heat resolves the pitch and oils into permanent gases and carbon.

"4. In all cases of ordinary combustion, carbonic acid is formed by the action of red-hot cinders on the oxygen of the air, and is accompanied by the nitrogen of the air. This carbonic acid is discharged in general as an invisible gas.*

"6. Black smoke is always associated with carbureted hydrogen gases, composed of carbon and hydrogen in various proportions. These may be mechanically blended with the oils and re-

*mber 5 is omitted here, as it is explained particularly in paragraph 529, hat follow it.

sins, but must be carefully distinguished from them. They form more essentially, when in a state of combustion, the inflammable matters that constitute flame, the luminousness of that flame being enriched by the amount of carbon, and of oily and resinous matter associated with it.

"7. SMOKE that contains much oily and resinous matter at one part of a furnace, may become, in a great measure, carbonaceous and gaseous at another.

"8. The richer a gas is in carbon, the more apt is it, when heated intensely, to become decomposed, and deposit black carbon.

"9. The elements, in ordinary coal, are carbon, oxygen, hydrogen, and nitrogen. In all cases when the combustion of the coal is complete, carbonic acid, water, and nitrogen gas, are the sole products, whatever intermediate products may be formed, and appear for a time as carbon, oils, inflammable gases, &c.

"The carbon of the fuel, with the oxygen of the air, forms the carbonic acid.

"The hydrogen of the fuel, with the oxygen of the air, forms the water.

"Any oxygen in the fuel assists the oxygen of the air in the production of these compounds.

"The nitrogen, both of the air and of the fuel, is detached.

"10. In peculiar furnaces, carbonic acid may be formed and decomposed many successive times before the final product is evolved.

"11. The drier and the warmer the air, the more does the watery vapour become dissolved in it. In a cold and damp atmosphere, the non-absorption of the watery vapour adds greatly to the apparent bulk of smoke, forming then vesicular vapour, similar to what is observed in a cloud.

"12. When coal contains sulphur, this element may appear—

"1. As sulphur, if simply sublimed without coming into contact with air.

"2. As sulphurous acid, if oxygenated (sulphuric acid is formed by further oxygenation).

"3. As hydrosulphuric acid, if combined with hydrogen.

"4. As sulphite, sulphate, or hydrosulphate of ammonia, if acidified by oxygen or hydrogen, and then combined with ammonia.

"5. As bisulphuret of carbon, if combined with this element.

"These remarks explain the more leading points connected with the production of black smoke. To enter into further details, would be to introduce an extensive series of questions, which have largely engaged the attention of modern chemistry, and opened a field of discovery in the formation of new compounds apparently inexhaustible, and bearing intimately on many of the minute changes attendant on the combustion of fuel.

"13. When the draught of a furnace is powerful, minute fragments of raw coal occasionally appear in the smoke.

"II. SMOKE from charcoal, coke, and anthracite. In this case, the smoke is always invisible, if the material be dry, nothing but carbonic acid or carbonic oxide gases being formed, according to the supply of air. A flame may appear, however, if carbonic oxide be formed by part of the carbon, as yet unconsumed, decomposing the carbonic acid in the manner already explained. The gases escaping are mixed necessarily with the nitrogen of the air from which the oxygen has been taken.

"III. WOOD SMOKE or PYROLIGNEOUS SMOKE is rarely black, the large amount of gases evolved carrying them away before they can be subjected to that intensity of heat which alone determines the production of thick black smoke. The gaseous products are essentially similar to those from coal in their leading features in respect to combustion, however different many of them may be in individual properties, and in particular, wood smoke is in general highly acid (pyroligneous or acetic acid being present); and hence the extremely irritating nature of the products, compared with those from coal, the latter being ammonia-and alkaline. Both contain carbonic acid.

" Water and carbonic acid are the products of the combustion of wood.

" SMOKE evolved in the various manufacturing operations, carried on in chemical works, contains frequently, in addition to the preceding substances, peculiar matters separated from the materials employed, and modified more or less by the action of air or fuel, of which the following may be taken as examples :—

" IV. SULPHUREOUS SMOKE.—Tons of sulphur are annually evolved, in various conditions, from copper-works. Offensive sulphureous smokes, visible or invisible, are often evolved from various chemical works.

" V. HYDROCHLORIC ACID SMOKE is evolved in general in larger quantities from alkali works.

" VI. METALLIC SMOKE, as from lead, copper, and arsenical works, the offensive matter consisting in general of the oxidated metal, in a minute state of division, and suspended in the air.

" VII. EMPYREUMATIC SMOKE from organic products, as from all varieties whatsoever of animal and vegetable matters, evolving offensive products on the application of heat, all of which, in the same manner, as the emanations from drains, can be completely destroyed, and rendered as inoffensive as that from a common fire, by subjecting them to heat before they escape into the external air.

" VIII. PUTRESCENT SMOKE, loaded with the products of decayed animal and vegetable matter, is evolved, in some cases, from manufactories, and also from drains, in visible vapours. more especially in damp weather, when the barometer is low. The fœtid particles associated with moisture in this smoke are entirely decomposed when subjected to heat. At the Houses of Parliament, at the Queen's Bench Court, at the York Road Hospital, and at various other places, shafts have been erected for this purpose. In the year 1831, the exhalations from a boiler charged with twenty tons of blubber, for the preparation of train-oil, were rendered imperceptible in this manner."—See Report on the Smoke Nuisance by the Committee of House of Commons, 1843.

QUERIES (See Par. 142, 143.)

For consideration before determining ventilating arrangements.

1. Is the external air pure, or is it subject to contamination from inefficient cleansing or drainage, or the evolution of vitiated air from drains.

2. If the external air be vitiated, can it be improved with facility, and does the surface of the ground require any lime, chloride of lime, or other materials, to bring it to a proper condition?

3. Is the vitiated air from dust-bins, sculleries, kitchens, &c. secured and discharged by an independent channel, or does it pass into the apartments generally by halls and passages?

4. In what mode is the ingress of air regulated?

5. What is the total area of openings for the ingress of air?

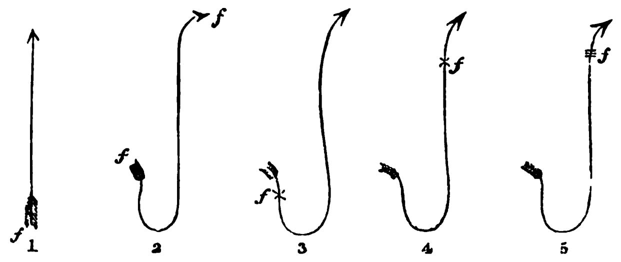
6. What is the total area for the discharge of vitiated air?

7. Is the air discharged by chimney-flues, or appropriate ventilating channels?

8. Does the air enter from the level of the ground, and is the surface in the vicinity protected from impurities?

First Series of Diagrams.

9. Does the air ascend directly from below and escape above, being protected from external currents (Diagram 1), or is it sub-



ject to any force, external or internal, tending to alter its course?

10. Is the impetus of wind upon the ingress much more powerful from some quarters than from others, and does it flow as shewn

in Diagram 2, the force of wind at *f* controlling all its movements, and is any valve provided to regulate its action?

11. Can artificial power be placed at *f*, Diagram 3, to force in a supply of pure air, should it be required on special occasions?

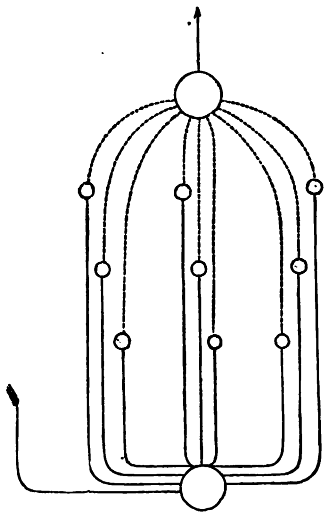
12. Or is the application of power there altogether impracticable, though it may be introduced with facility at *f*, Diagram 4.

13. Is a mechanical power at *f* (Diagram 4) too troublesome, and can a fire, a candle, an oil-lamp, or a gas-lamp, be used at *f*, Diagram 5, with perfect security against any danger from fire? Or can any lamp in use be employed for an equivalent purpose?

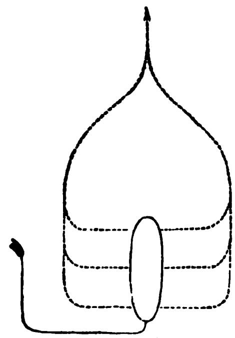
Second Series of Diagrams.

14. In more complex structures, is the air allowed to enter as accidental circumstances may determine, or is each room supplied by a regular and appropriate channel.

15. If this be the case, and the large circle, Diagram 1, in-



1

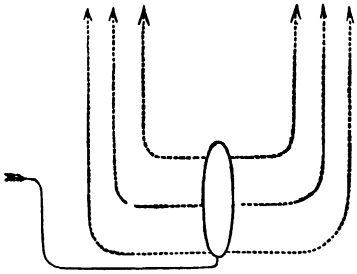


2

dicate a reservoir, in which air can be prepared or used as it

enters, the smaller circles representing individual apartments supplied from it, and the upper circle pointing out the vitiated air before it be discharged, then are valves arranged so as to isolate individual apartments not in use, so that there need not be any loss or expenditure either of warm air, or of ventilating power upon them ?

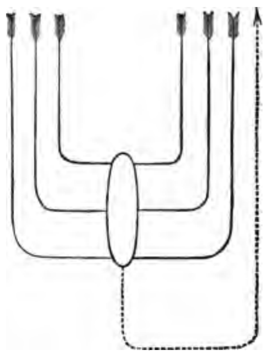
16. Can the hall and passages, Diagram 2, be made the reservoirs of heated air, instead of fitting up a separate chamber for this purpose ? If it shall have been impossible to gather all the ventilating channels in one external discharge, are the separate discharges, Diagram 3, so freely supplied with air, and so



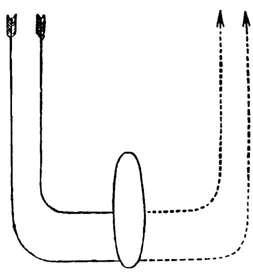
3

protected where they meet the external atmosphere, that the vitiated air from them escapes with facility ?

17. Is the kitchen so imperfectly supplied with air, Diagram 4,



4



5

and the fittings of external doors and windows so tight, that

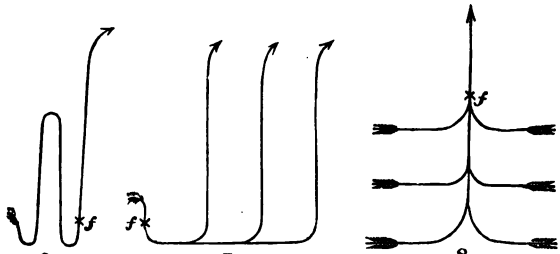
the kitchen draws down air from the hall or passages, which receive air from the adjoining apartment, and renders them all liable to smoke, no adequate supply being provided for it?

18. Do some of the apartments smoke, and supply air to others through the intervening passages, Diagram 5?

19. Is the case such, that vitiated air at the ceiling or roof cannot be certainly discharged without power,—that this power, from local circumstances, cannot be applied there; and that it is necessary to erect a power at *f*, so that the air which is discharged shall be conveyed from the ceiling by an air-tight channel to *f*?

20. Is it better, from the circumstances of the case, to blow in air entering by one channel, so as to supply an air drain, which which shall give air to each individual apartment, Diagram 7?

21. Or is it preferable that each separate apartment shall be



6 7 8

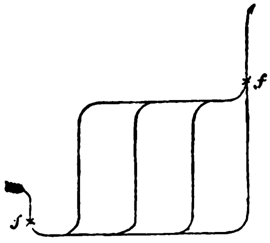
provided with an independent ingress, though these may terminate ultimately in a common egress, where a fire or a mechanical power may be applied above, Diagram 8?

22. Do the peculiarities of the structure render it advisable to trust solely to a power placed above at *f*, or are there peculiar occasions for which extra provision is indispensable, the power there not being sufficient, extra force being then also applied at *f* below, Diagram 9?

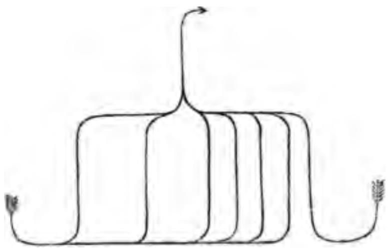
23. Is even this provision not sufficient in the case under consideration, and must some special additions be made to enable matters to proceed with satisfaction? See Diagram 10, page 49.

24. Do the arrangements indicate the necessity of two separate channels for the ingress of air, however unequally they may

be subdivided, though they may ultimately terminate in one external discharge, Diagram 11 ?

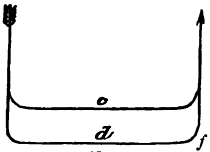


9



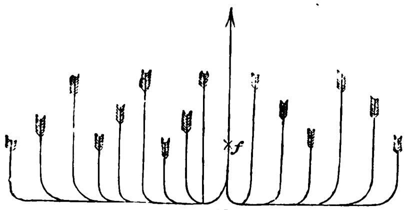
11

25. Is it an object, when the air which enters is divided into two portions, each passing to very different channels, *c* and *d*, Diagram 12, that the air from *c* should not enter an ascending shaft, except at some distance above the fire-place, that it may be far beyond any fire or flame, such as might produce dangerous effects ? Such arrangements are common in mines. When air proceeds from a part of the mine which gives out no offensive and inflammable gas, air from it may accordingly be led freely from it to the ventilating fire. But if *c* abound in fire-damp, it must enter at such an altitude as may prevent all chance of ignition from the fire below, Diagram 12 ?



12

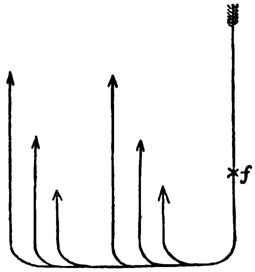
26. In houses, ships, mines, and manufactories, the position of the discharge for vitiated air cannot be too central, as then the vitiated air has not in any case to traverse so great a distance as might otherwise be necessary. Diagram 13 represents the



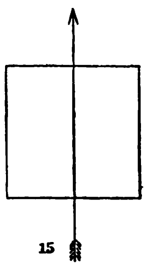
13

movements that might be induced from the ceiling of three dif-

ferent decks on board ship, were a central ventilating power or force applied at *d*. Such a power is occasionally arranged, so that its action may be reversed by a very simple movement. Diagram 14 illustrates a case of this kind. But when air is blown into different decks or apartments, the apartments above that are best for the egress of vitiated air, are not always the most suitable for the ingress of fresh air.



14



15

27. In looking to the movement of air through individual apartments, its effects are often exceedingly local, if one aperture for ingress and another for egress be alone provided, Diagram 15. But if these apertures be extended, so that the air be diffused more equally throughout the apartment, a small quantity of air produces much greater effect, an offensive local current is prevented, and a less elevated temperature is necessary than would otherwise be required.

PRINTED BY NEILL AND COMPANY, EDINBURGH.

INDEX.